# MODELING THE EFFECTS OF MULTICONTEXTUAL PHYSICS INSTRUCTION ON LEARNER EXPECTATIONS AND UNDERSTANDING OF FORCE AND MOTION SYSTEMS

By

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Sara-Maria Francis Deese Becht

This dissertation is dedicated to every precious member of my family -

especially my husband and children, Dr. Paul Becht, Sean Becht, and Laura Becht,

my parents, James Henry and Mary Catherine Deese,

and in memory of my former chair, Dr. Mary Budd Rowe.

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By

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Chairman: Elroy J. Bolduc, Jr.
Major Department: School of Teaching and Learning

The purpose of this study is two-fold involving both practical and theoretical modeling components. The practical component, an experiential-learning phase, investigated a study population for effects that increasing levels of multicontextual physics activities have on student understanding of Newtonian systems of motion. This contextual-learning model measured learner convictions and non-response gaps and analyzed learner response trends on context, technology, challenge, growth, and success.

The theoretical component, a model-building phase, designed a dynamic-knowing model for learning along a range of experiential tasks, from low to high context, monitored for indicators of learning in science and mathematics: learner academic performance and ability, learner control and academic attitude, and a learner non-response gap. This knowing model characterized a learner's process-of-knowing on a

less to more expert-like learner-response continuum using performance and perspective indices associated with level of contextual-imagery referent system.

Data for the contextual-learning model were collected on 180 secondary subjects: 72 middle and 108 high, with 36 physics subjects as local experts. Subjects were randomly assigned to one of three experimental groups differing only on context level of force and motion activities. Three levels of information were presented through context-based tasks: momentum constancy as inertia, momentum change as impulse, and momentum rate of change as force.

The statistical analysis used a multi-level factorial design with repeated measures and discriminate analysis of response-conviction items. Subject grouping criteria included school level, ability level in science and mathematics, gender and race. Assessment criteria used pre/post performance scores, confidence level in physics concepts held, and attitude towards science, mathematics, and technology. Learner indices were computed from logit-transforms applied to learner outcomes and to study control and prediction criteria parameters.

Findings suggest learner success rates vary with multicontextual experience level. When controlling for context, learner success seems to depend on technology level of assessment tool, learner attitude toward technology learning tools, learner attitude toward science and mathematics, and challenge level of force and motion problems. A learner non-response gap seems important when monitoring learner conviction. Application of the knowing model to the study population pictures learners on a journey towards success referenced to a local expert response.

# CHAPTER 1
# INTRODUCTION

This study investigated learner response to real world varied contextual learning activities in an effort to understand and model the learners' ability to build and develop conceptual frameworks when presented with systems of force and motion. The interactive imagery needed to generate the diverse contextual settings utilized technology-based multimedia information landscapes. A knowing model is designed and built on learner outcome data that resulted from student participation in a task progression of instructional activities designed to promote learner awareness and understanding of force and motion concepts.

## Overview

The research for this study was designed to use technology with varied contextual simulation type activities in order to determine if students are better able to understand concepts after a more diverse contextual activity as opposed to a less diverse contextual activity. The focus for this study was on student response over a range of context-based force and motion activities grouped on context level. The effect being investigated is identified as the context effect; the effect of diverse contextual activities on students' conceptual understanding of a system of force and motion using technology. Innovative technology is used to provide learning experiences involving simulated real world, interactive imagery. Also, the researcher examined effects on student expectations that result from immersion in an intensive task progression of activities on Newtonian systems of motion. Data obtained from learners engaged in force and motion tasks at different context levels was used to suggest a knowing model structure for a population of learners. A knowing model is pictured with entry points for intermediate learners suggesting former

periods of conceptual change and providing learners with targets for continued conceptual growth. The learner is pictured as being on a journey towards mastery from more primitive and intuitive thought processes towards developing more expert-like conceptual resources.

The study population was sampled from secondary school science and mathematics students enrolled in P. K. Yonge Development Research School. Three middle school science classes and four high school classes, composed of three science classes and one mathematics class, were selected into the study on the basis of teacher interest, subject matter, and class schedule. A total of 72 middle school students and 108 high school students, with 36 physics students as local experts, were randomly assigned to one of three experimental groups. Students within each of these experimental groups were identified for ability level in science and mathematics, divided into good and poor science and mathematics ability level categories, and distributed among three experimental groups. The experimental grouping remained fixed during the entire course of the study.

## Statement of The Problem

The problem investigated by this study is the degree to which the contextual basis of problem solving enhanced using technology influences the learner's thinking patterns. This problem was investigated through the development of a working model that simulates the learner's approach to different problem solving scenarios involving multi-contextual technological enhanced activities. A context was used in the study as a bridge between the learner's cognition and the learner's belief systems involved in problem solving.

1. Students have been recognized as having difficulties learning science and a need exists to help students resolve difficulties when learning science. Student performance in science and mathematics in the United States is 27th out of 96 in the world (NCES Report 1997b).

2. Students experienced difficulties understanding concepts of force and motion and often their informal views conflict with formal scientific reasoning when studying Newtonian systems of motion (Hammer, 1991; 1994; Rowe & Holland, 1990).

3. Students experienced difficulties making reality links between natural, real world events and plausible representations of those events associated with force and motion concepts (Prosser, Walker, & Rosemary, 1996; Redish, Steinberg, & Saul, 1996; Rowe & Holland, 1990; Steinberg, Saul, Wittmann, & Redish, 1996; Trowbridge & McDermott, 1980; Viennot, 1979; Watts & Taber, 1996).

4. Students experienced difficulties using mathematics for problem solving in science (NCES 1997b; Abad, 1994; Fisher, 1992b; Foster, 1996; Germann & Aram, 1996; Lapointe, Mead, & Phillips, 1989; Mestre, 1986; Redish et al., 1996; Rowe & McLeod, 1988; Stinson, 1993; Van Heuvelen, 1991a; Wakefield, 1997).

5. Teachers experienced difficulties motivating students to solve problems in science (Adamovic & Hedden, 1997; Ault, 1989; Foster, 1996; Hollabaugh, 1995; Huffman, 1997; Leonard, Gerace, Dufresne, & Mestre, 1994; Snider, 1989).

6. Students experienced difficulties constructing a clear picture of a science problem and often miss the point that a teacher tries to make. Students often entertain views differing on the context of a problem under study before they begin to construct the mental images needed for understanding concepts related to that problem (Rowe, 1965; Rowe, 1968; Rowe & Holland, 1990) and (Palmer, 1997; Pushkin, 1997).

Context-based difficulties often cloud opportunities for conceptual development when learners fail to put forth the effort needed to obtain a clear picture of a problem under study. Context-based conceptual development in science has not been widely applied to classroom learning opportunities (McCullough, 1997; Palmer, 1997; Pushkin, 1997; Rowe, 1966; Rowe, 1968). Learning models have not focused on cognitive guideposts which students and teachers can use on the journey towards mastery in understanding concepts in science. More emphasis is placed on what a learner does not know than on what a learner does know by those responsible for the education of our youth (NCES 1997b; Lapointe et al., 1989; Mestre, 1986; Rhoton, 1996; Rotberg, 1990).

Focusing the attention of visual learners having a range of newly emerged knowledge structures on concepts in science has become highly competitive with the media on a daily basis. Instructional strategies that utilize innovative learning technologies need to be developed and incorporated into current science curriculum programs in order to take advantage of technology that is becoming more readily available to the classroom teacher nationwide (Appendix A).

## Need for Study

Investigations into context-learning have a potential to provide the researcher with a window on what is important to the learners' repertoire of conceptual resources when extracting the form, function and meaning of concepts. Behaviors by which the learner mobilizes closely associated mental imagery referent systems for building and modifying conceptual frameworks can be closely observed. Schemes the learner uses to classify attributes of objects and events on their similarities and differences and to develop a sense through pattern recognition of what applies or does not apply to some problem or condition can be identified. Educational research efforts may be more successful at understanding cognitive learning behaviors if research designs that utilize a context effect are used to control for learning behaviors. Anyone in a range of associated mental imagery layers can be connected with some experience suggestive of plausible representations of real world events, problems, and their solutions. This range of plausible representations can be associated with a range of learner responses to scientific thinking representative of learners differing in their emerging knowledge for understanding specific concepts in science.

Evolving thought processes are conceived of as occurring on some continuum, in the sense of building a conceptual framework, linking ideas, and modeling for instances. And research studies focusing on these kinds of conceptual changes need to be linked to some similar kind of continuum in order to more accurately shape the outcome of these studies (Appendix B, Figures B-3 to B-4). Context-based studies that help to connect the concrete aspects of a problem with the abstract aspects should provide better ways to describe

attributes over the spectrum of learners from novice to expert (Bloomfield, Dahl, & Paasch, 1996; Hubbard, 1994; Larkin, 1981; McCullough, 1997; Rieber, 1996).

Research findings indicate that novice learners hold a wide range of beliefs on basic concepts in science, and beliefs learners hold of the natural world tend to be naive, unstudied, and intuitive. Depending on how the learner reasons to those beliefs suggests whether the underlying beliefs are tightly or loosely held by the learner (Dykstra, Boyle, & Monarch, 1992; Halloun & Hestenes, 1985; Hammer, 1994; Main, 1990; Mestre, 1986; Peters, 1981; Prosser et al., 1996; Ridgeway, 1988; Smith, DiSessa, & Roschelle, 1993; Viennot, 1979). Also, research studies have shown that associative learning, learning by metaphors, is a powerful tool for shaping conceptual understanding (Ausubel, 1960; Ayerson, 1996; Flick, 1990; Fuller, 1993; Griffith, 1992). Providing the learner with opportunities to link multiple imagery representations of concepts and problems using associative techniques seems like a powerful way for helping the learner sculpt out knowledge structures and grow conceptual frameworks. The range of perspectives learners hold on conceptual themes, such as that of force and motion concepts, can be more readily exposed through carefully designed context-based studies. Context learning can be used to help learners shape their conceptual frameworks while research that looks for a context effect can be used to monitor learner progress towards shaping that framework (Appendix B).

When students enter classroom doors, hopes are that time and effort spent in the classroom will help them to leave as better thinkers and problem solvers. Designers of classrooms need to look at the big picture to create better microcosms inside the classroom through which learners have opportunities for making connections between concepts and real world problems. In order to construct domain specific knowledge structures, students need opportunities to grow into the concepts supportive of the knowledge structures. Students need time to try out things, to grope, wonder, explore, experiment, and test to see for themselves what does and does not work. Students need to understand the world in

which they live from plausible scientific perspectives, that often there is more than one way to solve a problem, and that specific tools have been designed to facilitate the process of scientific thinking and reasoning. Students need to become more aware of how to use tools for scientific thinking and more willing to put forth effort and time required of them in order to engage in experimenting and problem solving in a variety of ways. Students also need to become more aware of the unknown, develop a feeling for the challenge of the unknown, and a sense of control in the search for the unknown: an opportunity to make known what once was unknown using the tools and processes of science.

The current scientific educational research community is concerned, alarmed, and challenged by the needs of students in today's classrooms (AAAS 1989a; Carnegie Council on Adolescent Development 1989c; National Research Council 1990; Educational Research Services 1996; Corrigan, 1992; Fisher, 1992a; 1992b; 1992c; Toffler, 1990; Yager, 1994; Young, 1993). Both educators and researchers need to be engaged in a new search for identifying parameters that control for quality and successful learning engagements. Constructing assessment instruments that are sensitive to conceptual growth opportunities is needed. Building models reflective of how students learn, what students learn, and what they need to learn next in order to grow useful knowledge structures could open doors to new worlds of learning. Today, learners need knowledge structures that will help them continue as lifelong learners in our complex world. And educators and researchers need to solicit the help and support of school administrators towards addressing the students' cognitive needs for learning science and mathematics in today's classrooms (Appendix A).

## Background

Understanding the difficulty students have developing meaningful conceptual knowledge about science and its real world applications has become a major concern for the physics education research community. More than two decades of misconception literature has documented major difficulties students have in understanding Newtonian systems of

motion. This literature has suggested a need to identify powerful instructional strategies that would encourage student conceptual development in the physical sciences.

This investigator considered that perhaps students need more breadth than depth during their initial conceptual formations. If instruction could utilize a broader, relevant experience base for students' conceptual development, then perhaps students would be more ready to make the contextual associations which lead to understanding the underlying principles of related systems. Realizing that most instruction on a particular science concept is carried out within a single contextual setting, it occurred to the researcher that variation in the contextual setting might be the missing link by providing more diversity to a student's opportunities for conceptual development. Advances through the new technologies provide a capability of interactive imagery and make it possible to prepare needed activities offering students varied contextual learning experiences.

## Purpose of Study

The purpose of this study was to investigate whether or not contextual associations of an underlying conceptual theme made between context-based experiences that are different but related cause such experiences to be more meaningful for the learner. The study investigation was two-fold involving both a practical and a theoretical component. The practical component was an experimental phase used to investigate the effects that a range of contextual learning activities has on student understanding of Newtonian systems of motion. The theoretical component was a model-building phase used to design a knowing model reflective of the study population on four indicators: (a) academic ability; (b) attitude towards science, mathematics and technology; (c) knowledge of force and motion concepts; and (d) tenacity of belief in force and motion concepts. The practical component of the study investigates learner response to real world varied contextual learning activities in an effort to understand and model the learners' ability to build and develop conceptual frameworks when presented with systems of force and motion. Learner outcome response resulted from participating in innovative instructional activities designed for developing

concepts about force and motion. These innovative instructional activities engaged the learner in a task progression of hands-on, interactive, technology based multi-modal, multimedia activities involving Newtonian systems of motion. The instructional delivery system focused learners' attention on force and motion events using a range of diverse multimedia contextual-imagery referent systems. The activities were designed to engage the students in tasks for investigating the laws of motion used to define and explain the behavior of a moving body.

The theoretical component was an empirical knowing model that provided ways for assessing student conceptual change towards understanding and mastery of force and motion concepts. This knowing model was built using investigations of learner outcome resulting from participating in innovative instructional activities designed for developing concepts about force and motion. The learner outcome from the identified treatment provides the range of level of knowing data that can be used to define a knowing model. Such a model might reflect the learner state of knowing in terms of what the learner knows at some point in time and what the learner needs to know in order to attain mastery of a set of concepts within the learner's own knowledge structure. Shaping the knowing model with the learner's ability level in a field of study provides clues to possible ways for structuring information intended for concept development when delivering instructional activities to learners having some estimated state of knowing regarding those concepts.

## Research Questions

Research questions addressed in this study were designed around five interactive visual learning tasks. These five tasks are probeware (pw), starfield (sf), model building (mb), real world (rw), and flight (ft). An overview and additional details of these tasks are presented in Appendices D and E. Research questions addressed in this study follow.

1. Is there a significant difference between middle school students and high school students in their abilities to understand force and motion concepts presented through a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) when these visual tasks occur in experimental groups (context level 1, context level 2, context level 3) based on level of context rich representations (from less diverse and definitive to more diverse and definitive) and in which the conceptual level (inertia, impulse, force) of information presented has been varied?

2. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied?

3. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied due to an interaction effect of student achievement level in science and mathematics (good, poor) within school level (middle school, high school) with experimental group?

4. Is there a significant difference in students' abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied?

5. Is there a significant difference in students' abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of the conceptual level (inertia,

impulse, force) of information presented and the school level (middle school, high school)?

6. Is there a significant difference in students' abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of the conceptual level (inertia, impulse, force) of information presented and student achievement level in science and mathematics (good, poor) within the school level (middle school, high school)?

7. Is there a significant difference in students in their abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of the conceptual level (inertia, impulse, force) of information presented and the experimental group (context level 1, context level 2, context level 3)?

8. Is there a significant difference in students' abilities to understand force and motion concepts at three conceptual levels (inertia, impulse, force) presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to the type of interactive visual task (pw,sf,mb,rw,ft) used?

9. Is there a significant difference in students' abilities to understand force and motion concepts at three conceptual levels (inertia, impulse, force) presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of visual task (pw,sf,mb,rw,ft) and school level (middle school, high school)?

10. Is there a significant difference in students' abilities to understand force and motion concepts at three conceptual levels (inertia, impulse, force) presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of task activity (pw,sf,mb,rw,ft) used in the visual and experimental group (context level 1, context level 2, context level 3)?

11. Is there a significant difference in students' abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to the interaction effect of the conceptual level (inertia, impulse, force) of information presented and task activity (pw,sf,mb,rw,ft) used in the visual?

12. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied due to an interaction effect of student locus of control (internal, external) within school level (middle school, high school) with experimental group?

13. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied due to an interaction effect of student perceived usefulness of instructional activities (helpful, not helpful) within school level (middle school, high school) with experimental group?

14. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied due to an interaction effect of force and motion checkpoints (applied force constant, distance rolled constant) within school level (middle school, high school) with experimental group?

15. Is there a significant difference among experimental groups (context level 1, context level 2, context level 3) in their abilities to understand force and motion concepts when these concepts are presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) in which the conceptual level (inertia, impulse, force) of information presented has been varied due to an interaction effect of student expectations of science, mathematics, and technology (good, poor) within school level (middle school, high school) with experimental group?
16. Is there a significant difference in students' abilities to understand force and motion concepts presented in a progression of five types of interactive visual tasks (pw,sf,mb,rw,ft) due to an interaction effect of the conceptual level (inertia, impulse, force) of information presented and student expectations of science, mathematics, and technology (good, poor) within school level (middle school, high school)?

## Philosophy

Diverse contextual and investigative activities that engage the learner's intellectual tendencies tend to promote a more fruitful extension of the learner's cognition as well as more meaningful learning experiences. The learning activities involved inquiry type situations that tend to facilitate a learner's cognitive development and disposition to think by encouraging associations between rich context-based visuals. Rich context-based visuals were presented using interactive imagery software delivery systems. These visuals provided contextual-imagery referent systems (CRS) for enhancing student opportunity for building mental models about force and motion from closely associated imagery events and representations which are also associated in an operational way with the target force and motion concepts. The use of rich contextual-imagery referent systems throughout the task progression of instructional activities reflects this investigator's belief that level of knowing is strongly associated with the type, variety, and amount of mental imagery available for the learner to make use of when building conceptual frameworks (Beichner, 1995; Bruner,

Oliver, & Greenfield, 1966; Dreyfus & Dreyfus, 1986; Rowe, 1968; Rowe, 1973b). And the learner's mental imagery referent systems associate strongly with visual imagery referent systems at any point in space and time which are presented to the learner in a way that allows the learner to utilize these kinds of visual referent systems.

Learners need time to experiment, to argue, to grope, and to understand how to make the unknown known. Problem solving is crucial for doing and understanding science. Students need to be active learners and active problem solvers. They need to engage learning in an energetic way, willing to put forth the effort required for problem solving and to recognize and overcome difficulties for doing problem solving tasks. Learning does not just happen all by itself; learning presupposes that the learner tries and puts forth effort to find out, discover, and experiment. Science is a process of inquiry and learning about the world in a special way, a way that brings the learner in touch with the unknown and allows for control of variables in a way that makes the unknown known and discoveries happen. Science engages the learner in the fabrication of knowledge structures from the known to the unknown and beyond.

## Instructional Strategy Model

This study investigated whether or not contextual associations of an underlying conceptual theme made between different but related context-based learning experiences cause the experiences to be more meaningful for the learner. The related context-based learning experiences were presented as visuals sufficiently different in form to encourage the viewer to make associations between events based on an underlying conceptual theme being developed rather than on observed similar physical features between the events. The contention is that more diverse experiences from varied contextual settings are more valuable than less diverse experiences when learning about an underlying conceptual theme. Three levels of contextual based experiences were constructed sufficiently dissimilar in physical features in order to build strength of relationship among the concepts of a conceptual theme being imprinted in the learner's mind. The contextual associations

allowed for different context levels of reality links or analogues, which the learner could use to organize mental structures of physical events and build a conceptual framework for an underlying principle theme common to these events.

The context-based progression of tasks on force and motion provided the learner with a task progression of activities, not in a sense of less to more things to do and attend to, but rather in a sense of moving from more concrete to more abstract situated imagery. Contextual-imagery referent systems were selected to assist the learner's development of an operant conceptual framework for studying systems of force and motion. These activities were designed to encourage habits of the mind in a way that enhances cognitive growth thought processes. Each learning task is realized as part of a continuous growth process towards understanding more clearly the basis of knowledge for thinking about systems reflecting physical motion phenomena.

Identifying context levels provided the investigator with a way to capture a range of possible contextual-imagery associations learners may possess when studying systems of motion. The context levels moved from less diverse and definitive to more diverse and definitive representations of contextual-imagery that identifies force and motion systems. The learning tasks at each context level moved the learner's focus from more concrete systems of motion to more abstract systems of motion. At each context level, the learner engaged in a series of activities that moved from studying systems of motion involving more concrete perspectives to ones involving more abstract perspectives on concepts of force and motion. The usage of contextual-imagery referent systems throughout the task progression provided the learner with mental associative imagery useful for referring back to physical phenomena.

## Theoretical Learning Models

### Constructivist Learning Model

The constructivist learning model provides insight into successful learner behaviors. An assumption basic to this model is that each learner must construct all learning. Learning

becomes meaningful for the student who spends time and effort extracting meaning out of what it is that needs to be done. Active learners make connections, conceptualize about things the way they are and the way they might be, engage in reasoning about why things are, build awareness, think about what they observe, and formulate new thought patterns as they seek explanations to their discoveries. Learning involves grabbing a hold of events, seizing a moment of existence, and actually doing something with what has been found. The learner must act upon whatever it is that needs to be studied. Successful learning demands a considerable amount of the learner's time: time for groping, exploring, experimenting, reflecting, putting together thoughts and taking them apart. The assumption that learners construct their own knowledge frameworks is supportive of behaviors required for learners seeking a better understanding of science. Scientists are tuned into their personal experiences. Scientists routinely carry out acts of exploring, explaining, testing, and experimenting. Scientists become actively involved in their environments. Scientists are people who do things in a logical, structured, organized, and measurable way.

Additional corollaries to the theoretical constructivist learning model, which is not unlike in premise to the empirical knowing model constructed for this study, follow.

1. By identifying with what is important, one is better able to recognize what is not important.
2. Experiential learning helps one more readily discover what is important in lieu of what is not important when it involves a continuum.
3. Learners need time for reflecting on what is important within a representation that refers to some concept in order to gain a better hold on that concept.
4. Learners need time for revisiting important elements of a concept so they become more sensitive to what makes them relevant and supportive of that concept.
5. Learners need time to consciously recognize and practice behaviors conducive to success in problem solving.

6. What to look for takes priority over what not to look for when building connections useful for constructing knowledge structures.

7. Assembly of important, salient parts is more effective for learning material that is new than assembly of what is unimportant.

8. When presented with new knowledge material, at first the learner is more child-like in not seeing relevant details until later when what is more relevant becomes manifested through experiential learning engagements that provide opportunities for sculpting knowledge structures.

9. A learner builds expertise in a knowledge area through exposure to a broad spectrum of experiential events, which appear at first to differ on context, then are found later to be closely associated on some underlying conceptual theme.

10. The pseudo ability a learner has for connecting limited real world for instances with abstract principles can be enhanced through strategies that allow for experiential learning opportunities during which the learner extracts knowledge relevant to the desired concepts.

11. Denuding a scene of background information for focusing the learner's attention on what is important is a time-consuming learned skill involving pattern recognition intermixed with a degree of artistic talent.

12. Familiarity with ones world raises the level of the subconscious and almost automatically involves the learner in an unconscious effort of removing trivial information whilst focusing on what is central and relevant to the concept.

13. Awareness of ones world is a background cognitive activity as opposed to a prominent foreground cognitive skill and is supportive for knowledge construction from imagery that is immediately presented to the learner.

14. Awareness of the interaction of dynamic elements in the imagery of closely related scenes and scenarios which seem to follow a temporal continuum is important for the learner's successful knowledge development and assessment.

15. Learners experience difficulties learning new knowledge and need ways for being more actively engaged in their own learning using resources from their environment.

**Cognitive-Belief Learning Model**

A cognitive model is needed--one that would really explain spontaneity in thought processes (Appendix B, Figures B-3 and B-4). A model is a step towards improving understanding of how and why humans think the way they do. But like any other model, once applied, the model is restricted by that set of rules on which it is based. Conway's game of life is limited to species that somehow follow the guidelines for his game. A careful observer and analyst can discover these ground rules by playing the game. Similarly, each individual plays the game of life and, as dictated by the individual's unique situation, tries to discover the guidelines according to which life survives. One way of doing this is to identify some major focal point and look for relationships between various activities and the focus. What are the rules, laws governing the interaction of events with the focal point and by what laws do events revolve about the focus?

Again, as long as one searches for these relationships and seeks out a basis for each, the discovery process goes on--and a fabric, a framework, for understanding can be woven then laid out. But once in place as the underlying laws for why life is what it is, then all future existence is bound and enslaved by such laws in order to function within the boundaries of that framework. Yet, should some essential value be treasured beyond the system--albeit freedom, love, hope, peace--then boundaries give way to a new existence, creation.

Thought, of its very nature, seeks out a framework from which to web more of itself, like a spider web, a spiral pathway expanding over and over, each likened to the other. But this is thought chained, enslaved to an establishment, to others' ideas, lacking free expression of itself. Hence creative thought--thought filled with fresh, refreshing new ideas--needs its beholder to be the creator, the author of its own framework. The author weaves a web different from all others and capable of a radically new design from time to

time--not lock step, not a replica for the sake of copy--but a web responding to spontaneity and freshness. The beholder's youthful fountain is likened to a refreshing spring of water that awakens its master as author to the energy flowing from within and outward into the world of reality. Thought itself being the essence of all reality has just those potentials. To be in fact means to exercise the ability to conceive as well as to have been conceived.

Closely related to thought is the awareness of thought. How frequently are learners not aware of what they actually think, or what they think they think is not in fact what they think. A learner's awareness level of knowing is akin to a state of believing in what in fact is known (Appendix B, Figures B-2 and B-4). But again, which comes first--believing in order to know or knowing in order to believe. This state of knowing dilemma is much likened to the uncertainty principle in which either the exact position or velocity of a particle can be quantified but not both at the same moment in time; somehow the quantities position and velocity are inseparable. Likewise a learner's states of knowing and believing seem to be inseparable. Expert learners seem to agree that mostly they believe what they do because they know, and what they know, they in fact believe. They often are not certain which came first: belief or knowledge. However, for learners to continue forward on a journey towards mastery of target concepts, they need support for where they are on this journey; they need to become more aware of their position on the road to mastery.

A model that summarizes learner profile in a simple way of where the learner's been, how far the learner's come, and how far the learner has yet to go for mastery of target concepts may alleviate learner frustration and serve to motivate more learners to achieve. Such a model that combines what one knows, cognition, with what one believes, belief, can be classified as a cognitive-belief model. An empirical knowing model has been presented through this investigative study as a way to address the need for a type of cognitive-belief model supportive of mastery learning. The empirical knowing model uses data collected from the sample population for this study to model the learner's condition,

state of knowing and believing. The design and application of such a knowing model is described in later Chapters (Chapters 3, 4, 5, and 6).

## Study Terminology

Since terminology used within the framework of this study takes on meaning unique to this study, the following terms are defined for this investigative study.

**Context** of an event concerns the circumstances surrounding the real world setting, the frame of reference for viewing in which a physical event occurs and the viewer's perspective or point of view about the physical happening.

**Contextual-imagery** of an event connects the learner to a referent system for accessing underlying concepts used to explain the event from a scientist's point of view.

**Hyperscience** involves the presentation of science instruction using interactive multimedia in diverse contextual instructional settings to facilitate learner success.

**Interactive Multimedia** pertains to the integration of sound, text, graphics and clips to portray an interactive simulation of a real world event.

**Multimodal delivery system**s indicate those organizers, simulations, activities and discussions utilized within the instructional format to guide students towards developing a well-founded conceptual-based understanding of real world events as they relate to Newtonian systems of motion.

**Paradigms** suggest the alternative frameworks of instructional strategies and multimodal delivery systems possible for enriched and expanded concept development through varied contextual activities.

**More diverse contextual-varied** activities and varied contextual instructional methods pertain to the usage of multimedia instructional resources that differ in the physical form they suggest but are similar in their reference to some common underlying concept.

**Less diverse contextual-varied** activities pertain to the usage of multimedia instructional resources that tend to be similar in both the physical form they suggest and in their reference to some common underlying concept.

**Learning transfer process** and **reality links** relate to opportunities for students to practice the application of some concept to diverse contextual, real world settings.

**Newtonian systems of motion** consider physical events involving motion defined within a physical system using Newtonian mechanics. Newtonian mechanics and Newtonian systems of motion refer to the usage of Newton's laws to identify and quantify physical events.

**A physical system** identifies all aspects of a physical event needed to identify and quantify the underlying concepts in science.

## Summary

Research in the field of physics education should explore the visual referent systems of instructional resources used in building conceptual frameworks. The researcher has focused and designed this study to focus on context-learning involving student understanding of force and motion concepts. The force and motion concepts presented were delivered in a progression of five types of interactive visual tasks and the conceptual level of information presented was varied on context level. The researcher has described the problem and identified a need for a context-based study in this chapter. Also included in this chapter is a synthesis of the related literature and the research questions addressed in this study. In addition, terminology used in the study is defined and explained and a more comprehensive list of study acronyms is identified and presented in Appendix P.

Chapter 2 contains a review of the literature to provide a practical and theoretical background from education research in science and physics on student difficulties understanding force and motion concepts. Chapter 2 also contains a review of research related to context-learning, learner imagery, and pattern recognition. The design of the research and procedures are described in Chapter 3. A description of the instructional strategy and design of a knowing model are included in Chapter 4. The results of the study and observational data are presented in Chapter 5. Chapter 6 contains the findings, discussion, implications, recommendations for future studies, and a summary of the study.

# CHAPTER 2
# REVIEW OF THE LITERATURE

## Learning Science

Scientific literacy, learning about the nature and processes of science, has emerged as a central goal of education. Despite this goal, recent studies indicate that by both national standards and world norms, education in the United States is failing to educate many students in scientific literacy and hence failing the nation (Fisher, 1992a; Lapointe et al., 1989). Responding to the urgent priority America has to reform education in science, mathematics, and technology, Project 2061 was launched just prior to the nineties (1989a; 1989b). Other reports on research studies as "The Science Report Card" (Mullis & Jenkins, 1988), "A Nation Prepared" (Carnegie Forum on Education and Economy 1986), and "TIMMS" ( see National Center for Educational Statistics, TIMMS Report 1997b; Rotberg, 1990) indicate that U.S. students demonstrate an inability to compete with students from other industrialized nations. These reports and others (Corrigan, 1992; Young, 1993) recognize the need for revitalizing instruction.

This urgency to develop more effective instructional strategies for educating youth in the nature, process, and function of science might best be understood from Einstein. Einstein saw the international presence of science as the construction of a collective scientific thought providing the scientific evolution of technologies impacting today's society. Einstein believed that scientific thought has its origins in the learner's careful observations of physical phenomena. Albert Einstein (1950) reflected on the emergence of science and its impact on society during the post war renaissance period of science and technology:

> What distinguishes the language of science from language, as we ordinarily understand the word? How is it that science language is international? . . . The super-national character of science concepts and science language is due to the fact that they have been set up by the best brains of all countries and all times. In solitude and yet in cooperative effort as regards the final effect, they created the spiritual tools for the technical revolutions which have transformed the life of mankind in the last centuries. Their system of concepts has served as a guide in the bewildering chaos of perceptions, so that we learned to grasp general truths from particular observations. (pp. 112-113)

Science can be said to exist in a synergistic relationship with technology: science begets technology and technology spurs onward the frontiers of science. Hence the importance of science in a global economy should be self-evident. For a nation to thrive as a world power, its people need to know, appreciate, and understand science and learn how to think scientifically.

Since the post war period, the computer has emerged through scientific endeavors as a significant technological innovation impacting all sectors of life as well as diverse frontiers of science. Understanding the nature of the computer as a high speed information processor and storage system, the technological revolutions occurring in education institutions involving teaching and learning seems only natural. And a high speed society is finding ways to implement programs "utilizing the emerging multimedia technology to enable (educators) to quickly and inexpensively craft educationally sound and eye-catching activities for mathematics and the sciences" (Kaplan, 1992, p. 53); also see (Fisher, 1992c).

Today, a complete restructuring of basic teacher-pupil relationship, functioning within both a visible and a transparent technology background, is needed to take advantage of the numerous emerging technologies entering schools, classrooms and the workplace (Carlson & Ruberg, 1998; Foti, 1996). Reflecting on the potential of the emerging technologies for dynamic change in the classroom, Rowe and McLeod (1988) stated "Today's technologies have the capacity to put everyone in touch with scientific concepts of both the past and the future. ...These electronic enhancements are actually changing how we think; how we arrive at the process of understanding" (Rowe & McLeod, 1988, p.13).

During the mid-sixties, a decade of national science curriculum development projects was launched (see Hurd, 1964). And in the mid-seventies, the National Science Foundation summoned a group of science educators to establish criteria for impact studies on the over-all effect of these multi-million dollar ventures (see Townsend, 1993). Recommendations included measurements of student abilities and action outcomes as transfer, logical reasoning, problem solving, laboratory investigations, and applications to real life situations. By the late eighties, another major program, Project 2061, promoted strategies for student involvement in science investigations (1989a; 1989b). "Learning science, mathematics, and technology should be a lively affair--active, participatory, non-bookish. But students are unlikely to build understanding of what the scientific enterprise is like unless they experience doing some of the same kinds of things that scientists, engineers, and mathematicians do in their work" (Rutherford, 1988, p. 2). This expectation for understanding science reflects Sir Roger Bacon's comment that "Without experience, nothing can be certainly known" (~1250 as cited in Rogers, 1960, p. 655). And Rutherford's words reflect those stated earlier in this century by Sir Percy Nunn:

> Encourage the love of observing and investigating natural phenomena, which is the mainspring of scientific life. Given that love, the mastery of scientific method becomes a natural incident . . . progress; without it, scientific method, however scrupulously "cultivated" is sterile. . . . The student must learn . . . what it is to face problems in the position of a real investigator, left largely to his own wits to wrest from nature the answers to the questions he puts to her. (~1918 as cited in Rogers, 1960, p. 655)

More recently, results from the National Science Education Standards Project provide additional support that to learn how to do science, students need to be involved in science-like behaviors. These include hands-on activities, inquiry and discovery opportunities, experimenting, project-based learning and scientific literacy (Bruder, 1993; Townsend, 1993).

## Learning Models

Several research-based learning models have been used during the latter half of the twentieth century to guide the study of how students might best learn to think scientifically.

These include heuristic models for learning science conceptually, problem solving models for learning science analytically, and constructivist models for learning science by inquiry. These models have been used largely to explore students' cognitive skills and to seek ways to improve upon those skills. Heuristic models are used to suggest logical ways for organizing conceptual based information and building better conceptual frameworks in a field of science (Van Heuvelen, 1991b). Problem solving models seek to suggest useful ways for organizing information used in analyzing and solving science-based problems (Gabel, 1989; Woods, 1989b). Constructivist models promote the belief that useful learning in science occurs when the learner constructs his/her own knowledge base of scientific constructs through inquiry and discovery (Atkin & Karplus, 1963; Saunders, 1992; Wheatley, 1991; Yager, 1991). Many research-based instructional strategies have been implemented to identify and help students surmount difficulties they experience when learning science by making conceptual shifts in their thinking processes and through guided discovery learning strategies (Pavelich & Abraham, 1977). Guided discovery learning has surfaced as structured learning opportunities using interactive lab-based tutorials (McDermott, 1996; Thornton & Sokoloff, 1992), interactive lecture demonstrations (Sokoloff, 1997), strategies for question-based discussions (Minstrell, 1982; Penick, Crow, & Bonnsetter, 1996), and collaborative group problem solving sessions (McCullough, 1997; McDermott & Shaffer, 1998). Guided discovery learning strategies, as opposed to free discovery, are associated with the scientific constructivist model of learning (Battista, 1999; Redish, 1999).

Constructivist learning models have been promoted by great thinkers of the twentieth century. Albert Einstein was keenly aware of the need to nurture learning in science through active learning. Referring to active learning, Einstein stated "But personalities are not formed by what is heard and said, but by labor and activity. The most important method of education accordingly always has consisted of that in which the pupil was urged to actual performance" (1950, pp. 32-33). He also commented

> The important thing is not to stop questioning. Curiosity has its own reason for existing. We cannot help but be in awe when we contemplate the mysteries of eternity, of life, of the marvelous structure of reality. It is enough if we try merely to comprehend a little of this mystery every day. Never lose a holy curiosity. (1950 as cited in Valentino, 1999, p.3)

Einstein was echoing views on learning carried over from the nineteenth century as indicated by DeGraff in the following passage:

> The method that should be pursued is that known as the objective method. This presents two distinct, though intimately related departments: perceptive teaching, in which the object, as an acorn, an egg, a leaf or a piece of coal is directly presented to the pupil's senses; and conceptive teaching in which impressions previously received are recalled, arranged and utilized. . . . Definitions should be very sparingly introduced, and never in the first stages of a subject. If given at all they should sum up knowledge already attained. . . . The vital element, that which gives it a living interest to the pupil, is the discovery or learning of new facts, or the gaining of new ideas about the objects under consideration. (~1879 as cited in Valentino, 1999, pp. 5-6)

During the fifties, Swiss psychologist Jean Piaget (1958) carried to a new level Einstein's thoughts on education and the science of learning. Through careful observation of young learners, Piaget found that the mind processes sensory data to create a coherent, world view that the learner envisions through the mind's eye. Piaget reasoned that people take their sensory inputs and extract meaning from them based on cognitive structures existing in the conceptual frameworks of their minds. The insight that Piaget contributed to learning theory was that if imagery plays a central role in a learner's thought processes, then the properties of that learner's imagery will have far-reaching influences, including constraints on the learner's cognitive processing involving concept development, reasoning, and understanding (Piaget, 1971).

Piaget's insights on learning had a major impact on learning theories in the later half of the twentieth century as well as on instructional strategies for teaching and learning. Rogers (1960), commenting on the course requirements of university schools, stated "Stress thoroughness of understanding more than completeness of coverage . . . encourage constructive thinking and careful experimenting" (p. vii). Roger further commented "To succeed, the course must encourage that depth of learning which comes with each student's own reasoning and creative thinking: the course must ask questions rather than hand out

results" (p. viii). Learning cones were created to aid in visualizing the gradient effect that increasing levels of involvement in experiential learning has on the learner's state of understanding (see Woods, 1989a, p. 109). Work by Kosslyn (1990) and fellow researchers found that learners possess different collections of components or sub-abilities for imagery processing. Their work suggested that "Depending on the efficacy of the individual imagery components, different people--and perhaps people of different ages--will be more or less well suited for performing specific imagery tasks" (Kosslyn, 1990, p. 996). This idea was developed by Dreyfus and Dreyfus (1986) in their model on the five stages of skill acquisition: novice, advanced beginner, competent, proficient, and expert. As the learner moves up the ladder of expertise in an area of science, the learner tends to express thought patterns associated with insight, the commonsense and intuitive logic of scientific thinking.

Explaining ways learners grow and develop expertise, theorist surmise that learners tend to construct and structure their knowledge-bases and develop and build their understanding for an area of expertise through learning cycles or patterns of learning behaviors. Learning cycles model ways that learners exercise constructive thought patterns and build a conceptual framework for greater depth of understanding. Rowe suggested learning is more likely to occur when learners are involved in continuous periods of exploration, inquiry, and discovery Rowe (1973b). Atkin (1963) and Karplus (1977) pictured learning as occurring through a spiral continuum involving the learner in periods of exploration, conceptualization, and application. Lawson (1999) described the basic learning pattern as a process of assimilation, disequilibrium, and accommodation of concepts. Battista (1999, p. 429) visualized how a learner's thought patterns mature through recursive cycles of action, reflection, and abstraction. Inquiry-based learning has been extended to the discussion cycle, a process for growing responsible learners as well as actively engaged cognitive learners. Discussion cycles use the inquiry approach to

learning science by exploring questions about knowing, actions, consequences, and values relevant to some object or event under study (Rowe, 1982, p.12).

Other advances in learning theory have considered the various cognitive learning styles that different students have for learning. The Myers-Briggs Type Index (Myers, 1962) was constructed to help learners become more conscious of their preferred learning channels when interacting with people, things, and concepts using four sets of polar indices for perceiving and deciding (intuitive versus sensory; thinking versus feeling; judgmental versus perception; extrovert versus introvert). Krausse (1998) reduced the Myers-Briggs Type Index to two sets of polar indices (sensor versus intuitive and thinker versus feeler) and developed a cognitive profile model of learning styles for studying differences in student achievement in a specific field of science, chemistry. Krausse noted,

> Prevailing wisdom is that we teach as we were taught, or if we've given it any pedagogical consideration, we teach as we learn. But we must do better than that. We must consider the ways our students need to learn, and teach to their strengths. We repeat the explanation of every major concept at least four times anyway. Instead of repeating the same explanation until it sinks in, we should try explaining it four different ways. (p. 59)

The need for structuring learning activities in ways that provide opportunities for learners to construct their own knowledge has been well documented in the literature (Gabel, 1994; Lawson, 1985; Rowe, 1982; 1990). Luft (1999) critiqued lab-based science learning through inquiry and suggested sensitivity to students' prior knowledge and the need for activities that force students to confront their current scientific ideas. As Luft (1999) explained,

> In order for students to learn science concepts, they need to have experiences that reveal and build upon their current cognitive schemas. When a student experiences a difference between an expectation and an observation, disequilibrium occurs and the student's schema can be modified to represent the experience. If disequilibrium does not occur, students may not fully understand the concept. Creating disequilibrium requires that students' prior concepts be revealed and challenged with evidence relevant to the concept. When students confront the evidence, they must make an explanation that expands or refines their current idea. (p. 42)

An underlying message being played out through research on learning in science is suggested by the dynamic interplay of two inseparable but recognized ways of knowing:

cognitive and affective. This message simply states that for a learner to know 'knowing', that learner must have first 'experienced' his/hers own learning. Restated, the development of a conceptual framework can be said to begin with the development of a contextual framework of related concepts through lived experiences (Piaget, 1971).

The personnel relevance of the learner's experience, individually and collectively at any given time, leads to a learner's state of knowing, spatial as well as temporal (Perry & Obenauf, 1987); that is, knowledge of the world in which the learner lives. One can imagine an active and responsible learner as one who is continually sensitive to and engaged in experiences that build on personnel relevance reflected by being caught up in dynamic learning cycles of self-exploration, self-understanding and appropriate action and direction (Rowe, 1982).

A learner that recognizes and engages opportunities to live out experiences and become more in touch with his/her own learning environment through inquiry can be envisioned as being one who builds a better sense of self-confidence needed for life-long learning. And a learner sensitive to the collective thoughts, ideas, and needs of others opens the doors to discovery, creativity and inventiveness. Researchers studying ways people learn and understand what they learn as well as more effective ways for learning tend to have a special respect and appreciation for the joy of learning and a desire to share the opportunities that this joy brings with others.

### The Learner's Imagery

Two decades of misconception research have revealed that oftentimes a mismatch occurs between the learner's intuitive thought or perception of physical phenomena and the formal scientific explanation of that same phenomena (Champagne, Klopfer, & Anderson, 1980; Halloun & Hestenes, 1985; Kyle, 1990; Laws, 1997b; McDermott, 1984; Minstrell, 1982; Rowe, 1982; Rowe & Holland, 1990; Treagust, Harrison, & Venville, 1996; Zollman, 1996). Efforts in the early nineties to assist student understanding of concepts in physics using a hierarchical scheme and multiple representations of real world problems

based on the concepts have proven successful (Dykstra et al., 1992; Mestre, 1993; Van Heuvelen, 1991b). Students were trained in cues and techniques for representing a problem in word, picture, physical and symbolic format. These same students were found to develop and use the appropriate linked mental structures which enable them to solve problems correctly more often than students not trained in these techniques (Van Heuvelen, 1991b). It could be inferred that developing skills for forming multiple representations of a problem in various formats involves the exercise of imagery abilities that assist in forming perceptions and finding relationships from physical phenomena involving the problem.

Kosslyn (1990), investigated selected mental operations involving imagery abilities used to invoke thought processes. Results indicated that the processing components, that is image generation, maintenance, and manipulation, needed to use imagery in thinking are age independent; however their speed of use decreases with age except for image maintenance which is nearly the same for an adult as for a child (Kosslyn, 1990). This is consistent with Piaget's (1971) mental imagery model and Phillip's (1981) thinking model that student response to a task follows a common sequential order using selected mental images.

But studies by Alport (1982), Kelsey (1980), Gunstone (1987), and Poduska (1986) have found large percentages of college-age students not passing Piagetian-type tasks involving concrete operational thinking. Motion studies by Phillips and Poduska (1986) and Perry and Obernauf (1987) suggest that when thinking about speed different individuals, having seen the same physical movement in their environment, think about speed differently because they have different mental structures allowing the same data to be processed or interpreted differently. Different individuals are in different stages of the sequence for acquiring mental structures as suggested by Piaget's model of intellectual development (Phillips, 1982; Piaget, 1958).

Piaget (1958) described the conceptual development of the learner as occurring through stages or levels of interaction with the physical world: sensory/motor, concrete,

pre-formal (intuitive/operational), and formal. Typically, an individual progresses from the sensory/motor level during early childhood, to concrete and intuitive during later childhood and adolescence years and finally to the formal level as an adult. Expectations are that college-age students possess mature adult minds capable of formal thought processes; these capabilities come from exposure to formal ways of thinking. But these expectations are inconsistent with findings from studies indicating that a large number of college-age students lack the mental structures associated with specific tasks for performing formal thought processes common to problem solving (Alport, 1982; Gunstone, 1987; Halloun & Hestenes, 1985; Kelsey, 1980; McDermott, 1984; Poduska & Phillips, 1986).

## Context-Learning

Fifty years of science education in America has shown that most classroom/laboratory instruction for conceptual development is done from a single contextual format as opposed to a diverse contextual experience base. Prior to the nineties, little systematic investigative effort beyond that of Rowe, Larkin, and Finegold had been done to identify the role of context in learning concepts (Finegold & Gorsky, 1991; Larkin, 1981; Rowe, 1965; 1966; 1968). Fortunately, recent efforts of a growing number of investigators have indicated a renewed interest in context-based learning as a significant element in students learning science (see Bloomfield et al., 1996; Dufresne, Gerace, & Leonard, 1997; Laws, 1997b; Palmer, 1997).

However, research-based literature on concept learning seems to have placed more emphasis on the intellectual development and the conceptual framework of the learner than on context-related issues. A learner's conceptual framework is thought to have a finite carrying capacity for concepts that must be learned, understood in order to master some area of study. Concepts are thought of as the fundamental entities in the knowledge structures of the mind which give meaning to real world happenings and allow one to reason, understand, create, and control events. But the role of context in learning, which

veils an underlying concept as it appears in the real world prior to being implanted into the learner's knowledge base, has been largely taken for granted.

Cronbach, considering the potential a learner has for growth through intellectual development, stated that "the depth of understanding, the range of application of a concept and the precision with which it is used can grow for years after the definition is learned" (Cronbach, 1963, p. 356). Suchman explained that "by manipulating 'cause and effect' ... the inquiring child moves beyond the concrete situation to higher levels of abstraction and generalization, using his/her own skills and powers of perception" (Suchman, 1960, pp. 42-47). Piaget theorized that selected mental structures or mental operations are needed to understand concepts well enough to apply them to higher cognitive processes (Piaget, 1971). Piaget recognized that these mental operations are rooted in numerous real-world experiences and that individual differences in points of view or perspectives are a reflection of the different types of mental structures individuals acquire from their experiences and implement in their responses. Rowe understood the importance of inquiry-based learning in science (Rowe, 1973a) and carried out research on measurable experimental indicators of context-learning in science (Rowe, 1968). Context-learning had finally been given a significant role in teaching and learning for students learning science.

A commonly held assumption in education has been that the more experiences a student has the more likely that student will be able to excel among his/her peers in the learning environment (Piaget, 1958). The implication is that students need numerous contextual-based experiences in order to gain depth in conceptual understanding. Yet, students are not likely to involve themselves in higher-order thinking skills that are conceptually based if they lack experiential learning opportunities linked to the concepts. And students who are enabled, by being involved in diverse contextual learning experiences providing links to underlying conceptual themes, are more likely to successfully apply these concepts in problem-solving situations (Redish, 1994).

But despite the high level of support for inquiry-based learning, contextual-based research appears to have remained largely a neglected area in the education research literature. Rowe, identifying context learning as an important area of education research in need of study, stated "Little explicit attention has been given to investigating the effects that contextual-based learning opportunities might have on concept learning in the formal classroom and laboratory settings" (1965, p. 12). One might wonder as Ward did that if Thomas Edison's "Invention Factory" provided a unique contextual environment which powered the mind of the most successful inventor in the history of the world, what might learning experiences in diverse contextual environments mean for today's students (Ward, 1982)? Studying the effect of context-learning on problem solving in the elementary science classroom, Rowe (1965) came to the following conclusion:

> Experience increases the probability that a particular alternative will be perceived as a possible successful solution to a problem. The accumulation of experience in different contexts which share common concepts increases the likelihood that a subject will successfully assign meaning to an event, i.e., recognizes that the event belongs to the class of possible solutions or conversely, recognizes that it should be excluded from the class of potential solutions. (p. 18)

Most certainly, what Rowe had inferred is that varied contextual instructional activities in science classrooms should provide students with a better operational understanding of science concepts.

## Pattern Recognition

The need for context-learning may be more rightly argued by the role pattern recognition must have in developing the learner's ability to understand and solve real world problems. Larkin (1981) has provided insight for addressing students' problem solving difficulties by stating the following:

> Much of what is required to solve problems in physics is not knowledge of principles of physics, but is instead an awareness of and insight into the conditions under which these principles operate. This awareness might be called 'common sense spatial knowledge'. It is usually not taught explicitly, nor emphasized (in any particular way). The source of many student difficulties may be the failure to use such knowledge. (p. 28)

She concluded that many science students lack the ability to make spatial inferences. Evidently, thinking as involved in problem solving involves not only specific sets of mental structures associated with the task but also the individual's awareness of possessing these mental structures and an understanding of how to invoke them in unique problem situations (Larkin, 1982). Belmont (1982) suggested that "learning to be a good thinker is learning to recognize and even search for opportunities to apply one's mental capacities" (1982: as cited in Resnick, 1987, p. 41). Resnick (1987) stated that the "research literature explains little on how intellectual tendencies (disposition for higher order thinking) develop" (p. 42). She thought that two concerns need be addressed, namely that "motivation for learning remains empty if substantial cognitive abilities are not developed and cognitive ability remains unused if the disposition to think is not developed" (p. 50).

Another important cognitive ability concerns skills needed for the organization and retrieval of knowledge. "Organization depends on the number and kinds of experiences one has had with elements and retrieval depends on the strength of their interrelationships" (Hayes-Roth, 1977, p. 270). Evidently, rich experiences linked to a common conceptual theme enhance an individual's observation skills by increasing the mental capacity for efficient pattern recognition. Once the cognitive workload for pattern recognition is reduced, more resources are available for higher and more complex mental activities. Larkin (1981) concluded that successful problem solvers use highly structured patterns of information, identified as spatial knowledge, to index and apply their knowledge. Dreyfus and Dreyfus (1986) studied and characterized learners' traits along a continuum and have described competent learners as those that:

> Learn to adopt a hierarchical procedure for decision making. By first choosing a plan to organize the situation, and by then examining only the small set of factors that are most important given the chosen plan, a person can both simplify and improve his performance. (p. 24)

The ability to know, understand, and recognize which sub-set of factors are important to a problem implies that pattern recognition must have an important role in the problem solving process. Being accomplished at pattern recognition means having an awareness of that

"small set of factors that are most important" (p. 24) to the problem or situation under study. And relevant stimuli and factors would seem more important than irrelevant ones for developing pattern recognition skills and abilities.

The importance for learners developing pattern recognition skills can be visualized as being a vital step towards bringing the learner into touch with intuitive thought processes, fuel for the inference engine that draws out real genius from the mind. Explaining the connectivity of pattern recognition to intuitive thought, Dreyfus and Dreyfus stated that intuition or know-how refers "to the understanding that effortlessly occurs upon seeing similarities with previous experiences" (p. 28). The intuition ability to use patterns without decomposing them into component fixations was defined as "holistic similarity recognition" (p. 28). Dreyfus and Dreyfus further stated that "intuition is the product of deep situational involvement and recognition of similarity" (p. 28).

The importance of pattern recognition in successful problem solving together with the commonly held view that most learners have an insufficient understanding about basic mental mechanisms involved in problem solving suggest an area of research in need of further study. Indeed, more investigations on how intellectual tendencies and intuitive thought processes develop together with studies on the role that varied contextual settings and multiple representations have in the development of spatial knowledge for successful problem solving are needed.

## Learning Physics

Research-based investigations by several physics education research groups about issues concerning students learning physics have been highly visible over the past two decades. Physics research groups have developed more effective instructional strategies to better deal with concept shifts, conceptual development, and problem solving abilities of physics students. A major concern for investigations carried out by these groups has been developing new instructional strategies for growing and empowering students learning

physics with well-founded conceptual frameworks and problem solving abilities needed for scientific thinking.

Studies by Van Heuvelen (1991b) and Mestre (1997; 1993) with physics students have focused on the importance of a hierarchical scheme utilizing multiple representations in understanding a concept. Students were focused on building a hierarchical knowledge structure of mechanics that spirals from lower to higher complexity in nature. The student's knowledge structure is matched with problem level difficulty to provide more opportunity for learner success in solving physics problems. Van Heuvelen (1991b) found that students studying mechanics and instructed in appropriate ways for building a hierarchical knowledge structure of mechanics performed significantly better than those receiving the traditional instruction in mechanics did.

Other studies with physics students (see Gorsky and Finegold 1991; 1992) have investigated the consistency with which individual students use force concepts, in different but closely related contexts. These studies are part of an on-going effort in the physics education research community to identify and restructure physics students misconceptions about force and motion (see Beichner, 1996b; Dufresne, Gerace, Hardiman, & Mestre, 1992; 1997; Flick, 1990; Galili & Bar, 1992; Hewson, 1985; McDermott, 1991; Redish, Saul, & Steinberg, 1997; 1998; White, 1984; 1989).

Cognitive models of mental processes for better understanding the conceptual change, conceptual framework and problem solving ability associated with student learning are being developed through research in physics education. Both Posner (1982) and Hewson (1984) have explored designs for conceptual change that support student learning in physics. They identified the underlying elements necessary and sufficient for invoking conceptual change, as through conflict resolution, in terms of qualitative descriptors or attributes for successful learning. A new conception is said to be adopted by the learner when the learner is conscious of this conception as being "intelligible, plausible, and fruitful" (Hewson & Beckett-Hewson, 1984, pp. 1-13).

Larkin (1980) modeled behaviors of student learning in physics from observations on the behaviors of novice and expert physics students. She identified physical intuition as a learning attribute having an important role in problem solving success. She characterized expert problem solvers in physics as being learners that draw upon their highly structured patterns of information to index and apply their knowledge. Novice problem solvers tended to have less developed conceptual frameworks from which to apply their knowledge and tended to be less capable of recognizing and applying underlying concepts needed for successful problem solving experiences in physics (Larkin et al., 1980; also see Larkin & Reif, 1979; Reif & Heller, 1982).

Research studies on laboratory innovations combined with microcomputer based laboratory (MBL) technology have suggested new avenues for improving student achievement (see Brasell, 1987; Germann & Aram, 1996; Laws, 1997a; Mokros, 1987; Redish et al., 1997; Thornton & Sokoloff, 1990). Students are encouraged to interact with a physical problem in their environment much the way a scientist does using microcomputer based laboratory probeware. The probeware and application software permit real-time data collection and monitoring of an interactive experiment through on-line graphical display and opportunities to view and manipulate the data sets off-line (Thornton & Sokoloff, 1995). Brasell also studied student interpretation of graphs produced from movement of their bodies and concluded that the immediate, interactive feedback and the multi-modal technology access to information defining an experiment seemed to provide students tools for understanding which are absent in the more traditional laboratory experience (Brasell, 1987).

Ways for improving student achievement also have been explored using computer simulations. Computer-based simulations have long been recognized as potential avenues for mastery learning, especially in areas which learners experience conceptual difficulties. Simulations have been designed that allow the learner to capture and model a real world event and experience for-instances of conditions surrounding that event. While director of

mathematics and computer education at the Berkeley Lawrence Hall of Science, Slesnick (1983) reflected on the power of the simulation as an effective instructional strategy:

> Researchers suspect that using simulations will help students understand the concept of modeling. This includes being able to distinguish between a model and reality, being able to identify the limitations of a model, being able to evaluate the information the model presents, and being able to distinguish between the real consequences of actions and hypothetical consequences of interaction with a model. (p. 30)

Bork (1980) described his work as a pioneer in the usage of computer simulations as good learning tools in the teaching of physics:

> Our most widely used student-computer dialogue is MOTION, an "F = ma" world for the student to explore freely. Students control, in a highly interactive manner, the force laws, equation constants and initial conditions. Thus they can examine many more situations than they can in the "real" world, with much more control. Further, they need not view the systems only in configuration (x-y) space, but can plot any two or three physically meaningful variables, thus moving toward viewing the system as existing in a wide variety of spaces normally unavailable. The very wide use of this dialogue by students not enrolled in physics classes testifies to its success. (p. 69)

Studies in physics education research have explored the usage of interactive computer simulations to help learners through concept shifts and towards ways of more formal scientific thinking about Newtonian systems of motion. White designed interactive computer simulations to help students experience and understand momentum change using force impulses to control a probe moving through a winding corridor (White, 1984; 1989). Zietsman investigated students learning kinematics using computer programs designed to diagnose learner difficulties and suggest remedies (Zietsman & Hewson, 1986). Flick studied the interaction of students' intuitive understanding of physics with computer - simulated physics (Flick, 1990). Gorsky investigated the usage of force and motion computer simulations as learning tools for restructuring students' conceptions of force (Gorsky & Finegold, 1992).

These studies and others attest to the scholarly inquiry being conducted by many physics education research groups regarding difficulties students have understanding concepts in physics and visualizing real world events in a more scientific way. Student

conceptual difficulties seem to have implications that reach beyond their knowledge base in science. Redish conducted a study that characterized learner expectations and reported a decline in student understanding for the process of learning in physics after taking university courses, either traditional or innovational (Redish et al., 1998). Even more disconcerting are the effects these learning difficulties seem to have on students' attitudes towards physics. Coleman reported on eight years of a university physics project the finding that "with increased exposure to physics, students liked it less" (Coleman, Holcomb, & Rigden, 1998, p. 137). Swartz (1997) reflected on why students often seem slow to develop an appreciation and understanding for the order observable, directly and indirectly, in nature, for the underlying laws governing that order, and for the inquiring habit of the mind and its role in learning science. Concerned for the seemingly dismal state of affairs in physics education research, Swartz shared the following insight: "Maybe our students aren't old enough yet. Maybe it takes several times around the topic, presented in many different modalities to begin to understand (concepts in physics)" (p. 5).

Most agree that innovative education studies have contributed to research-based literature becoming more sensitive to the learners' cognitive needs for successful growth and development of reliable thinking skills in the sciences. And findings from research-based studies on student learning in physics have provided a valuable resource to the science teacher seeking to improve teaching and learning strategies in the classroom. Observing the effect of education research on teaching in science, Swartz (1996) recognized that: "Maybe the chief value of an education innovation is that it is new" (p. 390). Others likewise have given testimony that the sharing of new and as well as commonsense ideas for facilitating teaching in science has long been a cherished tendency in the consciousness of the scientific community. Rogers (1960) introduced students to learning in physics with the following passage:

> Much of the difficulty of learning a piece of physics lies in understanding its background. When you understand what physics is driving at, the rules or calculations will seem sensible and easy. . . .To begin by discussing scientific methods or the structure of science would be like arguing about a foreign

> country before you have visited it. So we shall plunge at once into a sample of physics--gravity and falling bodies--and later discuss the general ideas involved. (p. 3)

### Summary and Research Focus

The research literature on student learning in science has become very active over the past couple of decades. This activity has been edged on by the perceived competition on the international scene but it is mostly due to a growing concern for the lack of progress students seem to make towards developing an understanding of science concepts after formal education from the high school to university levels. Particular attention has been given to students learning force and motion concepts in physics (Beichner, 1995; 1996a). Several studies have documented alternative views students hold on Newtonian systems of motion. Research-based studies have documented consistent findings on students' tightly held commonsense views. These studies found that students' alternative views seem to make interference with their ability to develop an understanding for certain concepts in science.

Learning theory has been used as a deductive tool for better analyzing and understanding why students seem to have difficulty learning science concepts. Studies by Piaget and followers have provided empirical evidence on an individual's conceptual development from child to adult and a basis for current scientific constructivist theories on learning. Scientific constructivists consider knowledge building and concept development to be learner-centered and that these processes can be effectively facilitated through guided-discovery learning activities (Ayerson, 1996). Most scientific constructivists have supported a student-centered learning cycle involving the exploration--inquiry--discovery approach to learning in science. Research intervention strategies for studying learner difficulties have included demonstration interviews, questioning strategies, think aloud sessions, learner concept maps, learner cognitive profiles, Vee diagrams, learner expectation studies, context rich problem sessions, tutorials in physics sessions, technology supported simulations, real time tools for scientific thinking, dynamically linked

video-graph simulations. Primary goals for these studies have been: to identify difficulties learners experience in understanding science concepts, to heighten learner awareness of their strengths and the skills they need to acquire, and to develop research-based instructional strategies for more effective teaching and learning of science and its disciplines such as physics and chemistry.

The Piagetian research literature has pictured the learner as moving through stages of expertise along a gradient from novice to expert in becoming an expert in some field of study or endeavor. Student conceptual difficulties understanding force and motion concepts have been documented for students from high school to introductory coursework at university levels and even graduate levels as well (McDermott, 1990). Researchers have found that students with conceptual learning difficulties have not let go of their learned commonsense views of the real world and that these students tend to lack formal methods for thinking scientifically about the nature of science. These students are most likely trapped in the concrete Piagetian stages of developing their thought patterns on underlying concepts of physics.

Since novice learners express naive tendencies for understanding concepts in physics, learning theory has suggested that these learners would be more likely to benefit from instructional strategies that involve relevant real world scenarios rather than more traditional approaches to teaching and learning science disciplines (Woodrow, 1995). Logic would suggest that context-based studies designed to identify instructional strategies for solving learner difficulties would be highly visible in the science education research literature on student learning in science. However, this is not the case in that relatively few context-based studies have been documented compared to the total collection of research-based studies on learning in science. Context-based studies explore strategies for helping learners make connections and develop concepts from a real world contextual reference frame as opposed to a more abstract conceptual reference system. Context-based studies are more

contextual than conceptual in character, dealing more with real world events identified as being relevant to the learner and with the diversity of real world occurrences.

Recent trends in the science education research literature have indicated a renewed interest in context-based research studies. But only a few research studies in the literature have reported on the context effect. The context effect concerns a learner level of response resulting from interaction with relevant, diverse, and differentiated real world instructional materials on a gradient from low to high context (Doerr, 1997; Palmer, 1997). Because contextual studies have their basis for investigation in the real world, ways for thinking about and implementing context-based studies appear to vary widely in the research literature. There exists no one recognized way for conducting and carrying out a context study and this area of educational research is still being defined. Methods for implementing and interpreting context-based research tend to vary from one study to the next. And context studies tend to be situational, concrete visual, and real world relevant to the learner. Hence, studies on learner imagery and pattern recognition were reviewed as an adjunct to research literature associated with context-learning.

Research studies have indicated that most secondary physical science activities provide little support and sensitivity to context as an instructional activity design issue (Rowe, 1968; Rowe, 1978), also (in Rowe 1978: \Bates, pp. 55-82; in Rowe 1982: \Hegarty, pp. 82-105). Redish has suggested that investigations that focus on a range of varied contextual real world and simulation activities may prove helpful in determining if students are better able to understand concepts after studying more varied or less varied contextual-based activities (Redish et al., 1997; 1998).

Grouping activities on context level provides a way to use context as the control variable and hence the ability to study the context effect. Context-based studies depend on the nature and properties of actual or imagined events, both physical and mental, presented to the learner. Interaction events with people, things, or ideas need to be presented in context, both spatially and temporally. Hence, context-based studies can be expected to

rely on a high degree of imagery and involve the learner in the spatial and temporal gymnastics of reasoning with objects and/or events, both in the real world and in the mind.

The visual nature of context-based studies can make them more inviting to research subjects because they tend to arouse a learner's curiosity and can be more naturally implemented into the learning environment. However, the presentation of an object or event in context can be a difficult challenge for the researcher to implement in practice because of the rules identified for an experimental control variable, such as context level, within the study and because of limitations within the learning environment.

When thinking about learning, a very basic question to ask is what makes learning happen? Using an experience-based approach to learning, one might surmise that being in closer contact with real world happenings allows easier learning pathways to successful learner outcomes. Think about some of the functional and conceptual things people do such as swimming, bike riding, driving an auto, flying a plane, and solving a problem. These activities have recognized risk-taking features within their different domains of operation or unique environments, but once learned, they seem to happen with ease.

Perhaps the secret to being an accomplished swimmer, rider, driver, pilot, problem solver lies in having, on various occasions, been totally immersed in a given specific activity on a gradient ramped from a more controlled and formal setting to a less controlled and more informal setting. Associated with each real world activity, are specific tools or objects that are made to function together according to specific rules or procedures by the learner engaged in that activity. As the learner becomes more adept in the usage of the tools within the rules of the playing field, the learner seems to implement the complex series of events required for a given activity almost effortlessly. Such a learner is imagined as moving from the lower tier of knowing and learning as a novice in the concrete operational stage of capability to the higher tier of knowing and learning as an expert in the formal operational stage of capability.

Since the lower tier of knowing what to do must by its very nature involve interaction with concrete objects in the context of their environment and purpose, then it seems only reasonable that context-based studies are a natural for probing, pursuing, and understanding the mysteries of learning. Spatial logic parameters have importance in context-based studies, but temporal logic parameters are also present. A natural approach to context-based studies is to begin with concrete-relations, just as a natural approach to wait-time studies is to begin with event-timing.

The areas of research-based literature explored that support context-based studies were selected by this investigator because of their natural association with learning in science and learner awareness of context-learning within real world informal settings (Laws, 1997c; Yager, 1991). Force and motion constructs are representative of a thematic area of mechanics important for students learning in science to grasp. These concepts have aroused the curiosity of mankind for several centuries. Rene Descartes (~1640) stated, "Give me matter and motion, and I will construct the universe" (Rene Descartes (~1640) in Rogers, 1960, p. 315). Force and motion are not only constructs of the mind, but have as their source for images of the mind real world for instances, events of everyday life. This real world immediacy of force and motion events lends these events more readily to visual representation through imagery, both physical and mental. Such physical representations are easier to visualize and eventually lead to the mental imagery needed to apply force and motion concepts to real world problems.

Physics research literature has documented learner difficulties in understanding basic concepts in physical science, which have their origin in real world events. Questions abound such as: What is a teacher to do? What instructional strategies are effective for guiding student learning in science? What do students really need to know? What are effective ways for taking students from not knowing to knowing? What difficulties might be present in different levels of cognitive thought and function? How different are abstractions in causal reasoning from reasoning by analogy, with episodes, with the

unseen, from experience? And if experience is the basis of it all, might not ones reason have, as a basis, the experience of its beholder?

Understanding the nature and processes of science in a functional way ultimately means understanding problem solving. Problem solving is recognized as a complex field of study in and unto itself, but at the same time it constitutes the analytical tool for every area of scientific endeavor. Problem solving requires abstraction, imagination, and creativity based on an understanding of whatever systems are presented as the object of investigation. Problem solving originates in inquiry, in the formulation of questions; and problem solving ends in questioning, in using ones findings to move toward new directions. Skill at problem solving in a particular area of science comes with the recursive use of tools identified for that science, a basic understanding of underlying relevant concepts, and the ability to apply for instances learned through experience to the particular problem of importance.

Both science and problem solving involve the learner working with data to get at the concepts that a collection of data suggests. They also involve understanding general concepts and using those concepts to express relationships about observable parameters present in systems and to determine quantitative information about a system. Current indications are that most people have little or no understanding about data and measurements. They appear to not know what or how to measure. They seem unaware of the role data has in giving testimony to an empirical relationship. And, they do not recognize how an empirically determined relationship might lead to the development of a new law or principle of science (Chien, 1997). A quantitative world seems to remain a mystery to most people, even as the technological tools of measurement continue to multiply. People seem lost that a set of numbers can be used to describe properties of an object or event and do not know how to find meaning in data. Yet the research literature continues to document that usage of technological tools for investigating real world

occurrences scientifically can cause powerful reversals and cognitive shifts for students learning in science (Eylon, Ronen, & Ganiel, 1996; Palmer, 1997).

An important finding, empirically documented in the research literature on learning theory, is that knowledge results from the learner's own construction of that knowledge; and knowledge is utilized, applied in solving problems, as learner understanding of the rules and functions for a given knowledge set mature. Thematic areas of science, rather than individual concepts, are more desirable for instruction and students learning in science. As a result of the recent national programs such as Project 2061, several themes in science have been identified as conceptual material to be known and understood. Since research-based literature on student learning in science has documented difficulties students have in learning force and motion concepts, the force and motion theme has received attention in the curriculum from pre-college through university levels.

But one must consider the reality that students come with different ways for thinking about material selected for study due to each student's unique collection of past experiences. A conclusion from this observation might be that nurturing an expert-like conceptual basis for science needs to be experienced based and that means starting with the concrete in ways that a selected concrete form is placed in a context which is relevant to concepts desired to be learned. And learning theory suggests that such relevant contextual for instances need to be referenced to a real world system relevant to the learner's environment. The opportunity to explore, inquire, and discover what can be seen leads more naturally to the cognitive ability to explore, inquire, and discover the unseen. The opportunity to model and interact with real world systems and visualize them dynamically leads to cognitive abilities for exploring the unknown, discovering the unseen, and designing new worlds yet unknown.

More activities which facilitate the learner's cognitive development and disposition to think by encouraging contextual associations are needed. Interactive imagery presented through multimedia systems can be used to create a varied contextual learning environment

with activities that enhance and extend the normal classroom/laboratory environment. Research on interactive imagery involving the human-computer interface has suggested more effective strategies for learning complex concepts (Brungardt, 1993; Carlson & Ruberg, 1998; Clemens-Walatka, 1998; Hein, 1997; Hooper, 1990). The belief is that multi-contextual, investigative activities which engage the learner's intellectual tendencies are likely to promote a more fruitful extension of the learner's cognition (an opportunity for conceptual shifts) as well as more meaningful learning experiences (Driver & Erickson, 1983; Hewson & Beckett-Hewson, 1984; Rowe & Holland, 1990).

The contextual associations for a concept being studied can be viewed as analogues that the learner uses to organize mental structures of physical events and build a conceptual framework for an underlying principle theme common to those events (Eylon & Reif, 1984). Hence, studies are needed to determine if contextual-based activities, which are sufficiently dissimilar in physical features, build strength of relationship among concepts underlying a conceptual theme and help this theme to become more firmly imprinted in the learners mind.

Emerging technologies are making new forms of information landscapes possible for presenting information so that individuals can more readily understand and grasp concepts (Foti, 1996; Fuller, 1993; in Ambron, and Hooper 1990, Hooper and Florin; see Laurel, 1991a; 1991b). These information landscapes can take on many forms including multi-sensory and virtual reality environments for engaging the learner in surrealistic experiences. Interactive multimedia systems rich in contextual imagery can help the learner develop better conceptual frameworks (Ayerson, 1996; 1980; Bork & Ballard, 1972; Carlson & Ruberg, 1998; Clark, Moore, Fuller, & Lang, 1996).

Technology tools are continuing to evolve rapidly toward a more intense virtual multimedia environment for learning allowing for a capability of delivering large amounts of information in a very realistic, virtual, multi-context format. Little research has been done that has documented the manner in which context rich multimedia can be most

effectively used in concept formation. If visual imagery opportunities for concept formation are to be used wisely and effectively in our educational setting, then research is needed to investigate the ways this tool can be used in the delivery of context rich instructional content.

Opportunities to become more aware of different perspectives, to alter the viewer's frame-of-reference, to view context related situations from different positions and viewpoints can be examined for their effect on an individual's thinking processes. As more multimedia programs using interactive imagery enter the learning environment, studying the intellectual development process will occur in ways never before imagined. Evolving interactive imagery will provide new worlds for students learning to think and utilize information effectively. Education in the new millennium is expected to be very different from the more traditional education programs of the twentieth century. And the new millennium is likely to see a core of research studies on teaching and learning using new technologies that continue to shape and structure learning theory. Future research studies should include research on context-learning for improving the teaching and learning of science. The finding by Rowe (1965) on the important role that context-based referent systems have on learner cognitive growth has been clearly stated as follows:

> Experience increases the probability that a particular alternative will be perceived as a possible successful solution to a problem. The accumulation of experience in different contexts which share common concepts increases the likelihood that a subject will successfully assign meaning to an event, i.e., recognizes that the event belongs to the class of possible solutions or conversely, recognizes that it should be excluded from the class of potential solutions. (p. 18)

This research study was designed to be a lighthouse for curriculum development pre-service teacher education programs that use contextual teaching and learning strategies to improve student achievement (see National School to Work Office, Contextual Teaching and Learning Report 1997a). These context-based strategies focus on students as active learners and provide a wide range of learning opportunities for them to use their academic skills to solve complex academic problems.

## CHAPTER 3
## DESIGN OF THE RESEARCH

The purpose of this study was twofold, involving both practical and theoretical modeling components. The practical component was an experimental phase used to investigate the effects that a range of contextual learning activities has on student understanding of Newtonian systems of motion. This phase of the study investigated learner response to real world varied contextual learning activities in an effort to understand and model the learners' ability to build and develop conceptual frameworks when presented with systems of force and motion. Learner outcome response resulted from participating in innovative instructional activities designed for developing concepts about force and motion. These innovative instructional activities engaged the learner in a task progress of hands-on, interactive, technology based multi-modal, multimedia activities involving Newtonian systems of motion. The instructional delivery system focused learners' attention on force and motion events using a range of diverse multimedia contextual-imagery referent systems. The activities were designed to engage the students in tasks for investigating the laws of motion used to define and explain the behavior of a moving body.

The theoretical component was a model-building phase used to design a knowing model reflective of the study population on four indicators: academic ability in science and mathematics, attitude towards science, mathematics and technology, knowledge of force and motion concepts, and tenacity of belief in force and motion concepts. The empirically defined knowing model provided a way for assessing student conceptual change towards understanding and mastery of force and motion concepts. The knowing model was built using investigations of learner outcome resulting from participating in innovative instructional activities designed for developing concepts about force and motion. The

learner outcome from the identified treatment provided the range for levels of data used to construct a knowing model that reflects a learner state of knowing. A state of knowing identifies what the learner needs to know for mastery of concepts in terms of what the learner already knows about those concepts at some point in time and the way in which this state of knowing has been shaped. Shaping the knowing model with the learner's ability level in a field of study provides clues to possible ways for structuring information intended for concept development when delivering instructional activities to learners having some estimated state of knowing regarding those concepts.

## Research Design

Each hypothesis was chosen to demonstrate the effectiveness or ineffectiveness of context-learning using an interactive visual task progression of instructional activities about force and motion concepts. Six main student behaviors were tracked: a) conceptual change of force and motion concepts, b) tenacity of belief for conceptual resources on force and motion, c) achievement in science and mathematics, d) expectations of science, mathematics, and technology, e) perceived successful locus of control in acquiring an understanding of momentum, and f) perceived usefulness of instructional activities for understanding Newtonian systems of motion. (Appendix B, Figure B-8; Appendix C, Figure C-1; Appendices H,I)

In the case of force and motion concepts, pre and post query items were selected from a Conceptual Physics test bank and modified using visual perception enhancement techniques such as wall-paper, color, and added multi-media visual information. The added visual information used techniques to command the learner's selective attention as highlighted hypertext and hotspots that brought forth well-labeled real world stills, associated imagery referent systems having mathematical and graphical representations, and vignettes of associated real world events, juxtapostioned and supportive of the query item being presented.

Formative force and motion query items in the form of student activity guide-sheets were used at each stage of the task progression of activities. A concept matching exercise enhanced for visual perception and supported with hotspots providing well-illustrated associated contextual-imagery, and two well-illustrated force and motion problem solving checkpoints using interactive associated contextual-imagery referent systems.

Tenacity that students showed for conceptual resources on each query item was identified by the shift in position from pre to post of item choice relative to what is favorable for that query item as identified by local experts. The local experts were high school current and past physics students having previously studied force and motion concepts and who participated in the study concurrently with non-physics type students.

Student academic records within school level (middle school, high school) were used to identify student achievement level in science and mathematics. Students having a B level or higher and a majority of advanced science and mathematics courses were ranked as good; students having a C level or lower and a majority of basic and remedial courses were ranked as poor.

Student expectations of science, mathematics, and technology were identified by pre and post surveys with attitude type questions having a Leichter scale of 1 to 5 using an agree-disagree paradigm. The attitude questions were taken from the All-School-Subject Attitude Test and adapted to this context-learning study using visual perception enhancements techniques described above. Individual scores each in science, mathematics, and technology and a composite score were obtained for each student. Response to each item (using the agree-disagree paradigm) was identified as being favorable or unfavorable relative to which response (agree or disagree) was selected by experts for that query item.

Multiple choice and open form self-evaluation questions were used to assess student locus of control upon completion of the study on force and motion. A resource critique open form question was used to solicit perceived usefulness of instructional activities from participants as a formative evaluation of the study. The self-evaluation and resource

critique type questions reflect a composite student locus of control. Also, the feedback critique will be used to improve the study for future use.

Because of the number of students participating and the timing of class arrival for the study, randomization was possible only in the selection of students into each of the three study experimental groups, two treatments and one control, without regard to ability level in science and mathematics, gender, or race. Hence, students from each class were randomly distributed among three multi-modal hi-tech workstations differing only in degree of context-based multimedia presentations.

The research design procedure used for this study approximates the Pre-test/Post-test Control Group Design No. 4 of the Campbell and Stanley (1969) series shown below with one additional treatment group added to the schema (p.13):

| | | | |
|---|---|---|---|
| R: | O3 | X2 | O3' |
| R: | O2 | X1 | O2' |
| R: | O1 | | O1' |

Again, each of the three experimental groups were identified by workstations differing only in degree of context on a scale from less diverse and definitive to more diverse and definitive multimedia presentations. The workstations having the least diverse and definitive multimedia presentations available were assigned to be the control group (O1, O1' in the above research design). The workstations having the next degree of context (X1 in the research design) were assigned to be treatment group 1 (O2, O2' in the research design above). The workstations having the maximum degree of context (X2 in the above research design) were assigned to be treatment group 2 (O3, O3' in the research design above). Degree of context of visual resources is equated with degree to which the activities presented were made to emulate real world event-situations and the number of contextual for instances associated with the real world event-situations available at the workstations. Similarity of visual resources in both structure and function to real world for instances of scenes, events and like representations are deemed important towards building the needed

degree of awareness that empowers the learner to utilize visual resources. Visual resources that make use of associative imagery referent systems hold clues from which the learner sculpts out conceptual mental models underlying a specific problem or happening. Varying the definition and diversity of context-based visual resources at increasing contextual-association levels, structured this investigative study involving context-learning of force and motion concepts to be sensitive for and hence identify the presence of certain context effects that impact learning opportunities.

The two treatment groups and the one control group that make up the three experimental groups are assumed similar because all subjects come from the same population of students and were randomly assigned into the three experimental groups and randomly placed at a multimedia workstation of the assigned quad. Furthermore, all students in this study were attending the same secondary school. If this assumption is correct, the threats to internal validity due to history, maturation, testing and instrumentation are controlled.

A force and motion pretest was used to determine the equivalency of control and experimental groups prior to treatment using the student t-test across all groups. Since all students selected into the study came from the same population, selection-maturation interaction was controlled. Since students were randomly distributed among the control and experimental groups, the threat of this source to internal validity is greatly reduced.

Both the effect of subject regression on internal validity and of the testing and treatment interaction as a threat to external validity were minimized as threats in this study since the pretest is given in advance of the treatment. Testing and treatment interaction as a threat to external validity does not seem to be a threat since the amount of time testing, compared to the amount of time treatment, is in effect small; so the student should remember testing instruments less clearly from pre to post. The threat of selection and treatment interaction is controlled since the generalizations are limited to the school in which the data was obtained and to those schools having a population similar to that of the school

selected for this investigative study. The effect of reactive arrangements on external validity is limited because like workstations were grouped together and workstations differing by degree of contextual resources outwardly appeared similar such that student sensitivity toward the experimentation was minimized.

A statistical analysis model, described in the next section of this chapter, will be used to test the hypothesis and to check the content validity of the study.

## Statistical Model Design

A statistical analysis of the data for this study used StatView (Sager, 1994), a statistical toolbox by Abacus, and an 8500 Power Macintosh computer. The analysis included population control measures, correlation relationships, and repeated measures. These procedures applied to the study are indicated below.

1. Population control measures used t-tests which included the following:
   (a) t-test on pre-test--Force and Motion Concepts, and
   (b) t-test on pre-test--Attitude.
2. Correlation matrices were based on Pearson's Coefficient of Correlation (r) for studying the relationships between variables for achievement and attitude or ability for both treatment and control groups.
3. Repeated measure analyses of covariance and variance test for significance difference between the control and treatment groups were carried out in terms of an ancillary variable, learner ability level in science and mathematics, and three dependent variables. The three dependent variables concerned the following:
   (a) mastery of force and motion concepts (3 factorial matrices),
   (b) attitude trend toward science, mathematics, and technology (1 factorial matrix),
   (c) learner perception for grasping force and motion concepts (1 factorial matrix).

The statistical design for the study involving concept mastery was a 3x3x2x3 factorial design with repeated measures (Table 3-1) (Appendix I, Figures I-6 to I-10). Repeated measures analysis of variance was used to analyze the data. The analysis studied the use of

three context levels, three concept difficulty levels, two ancillary ability levels, and three formal studied levels. Factor A (fA: experimental group, i = 1,2,3) consisted of three groups: context level 1 (control), context level 2 (treatment 1), and context level 3 (treatment 2). Factor B (fB: level of concept, j = 1,2,3) had three levels (from less complex to more complex): (a) momentum (inertia), (b) change of momentum (impulse), and (c) rate of change of momentum (force). Factor C (fC: level of ancillary ability factor, k = 1,2) consisted of two groups: (a) less than average (poor), and (b) average or greater (good ) for ancillary factors reflecting ability in science and mathematics. Factor D (fD: formal level of concept studied, l = 1,2,3) had three groups: (a) middle school (MS), (b) high school (HS), and (c) high school physics (HSP). Parameter Mijkl identifies cell values.

Table 3-1
Factorial design (3x3x2x3) with repeated measures on two factors (fB:3; fC:2)

| (fB: ) j | | p | | Δp | | Δp/Δt | |
|---|---|---|---|---|---|---|---|
| (fC: ) k | | good | poor | good | poor | good | poor |
| (fA:) i | (fD:)l | | | | | | |
| CL1 | MS | Mijkl | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |
| CL2 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |
| CL3 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |

The cell criteria values, Mijkl, for the concept mastery factorial matrix were subject responses on the physics concept instruments: pre/post, checkpoints 1 and 2, and tasks 1, 2, 3, 4, and 5. Each formal level studied was taken as a group response observation and each subject within that formal level studied as a repeated measure of that group observation. Overall, nine observations for all context levels (fA: 3) were evaluated by six different measures of concept difficulty level (fB: 3) and ancillary factor ability level (fC: 2) using three cell criteria measures for concept mastery. Subjects within a formal

level studied (fD) were randomly assigned to context levels (fA) and attended to tasks only at one of the three context levels. Also, each subject represented only one of the formal studied levels (fD).

The statistical design for the study involving attitude trends was a 3x3x2x3 factorial design with repeated measures (Table 3-2) (Appendix I, Figures I-11 and I-12). A repeated measures analysis of variance was used to analyze the data. The analysis studied the use of three context levels, three attitude trends, two ancillary ability levels, and three formal studied levels. Factor A (fA: experimental group, i = 1,2,3) consisted of three groups: context level 1 (control), context level 2 (treatment 1), and context level 3 (treatment 2). Factor B (fB: level of discipline, j = 1,2,3) had three trend levels (from more concrete and less abstract to less concrete and more abstract): (1) technology, (2) science, and (3) mathematics. Factor C (fC: level of ancillary ability factor, k = 1,2) consisted of two groups: (1) less than average (poor), and (2) average or greater (good ) for ancillary factors reflecting ability in science and mathematics. Factor D (fD: formal level of concept studied, l = 1,2,3) had three groups: (1) middle school (MS), (2) high school (HS), and (3) high school physics (HSP). The subscript parameter Mijkl identifies each cell value.

Table 3-2
Factorial design (3x3x2x3) with repeated measures on two factors (fB; fC)

| (fB: ) j | | technology | | science | | mathematics | |
|---|---|---|---|---|---|---|---|
| (fC: )k | | good | poor | good | poor | good | poor |
| (fA:)i | (fD:)l | | | | | | |
| CL1 | MS | Mijkl | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |
| CL2 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |
| CL3 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |

The cell criteria values, Mijkl, for the attitude trends factorial matrix were subject responses on the science, technology, and mathematics pre/post instrument. Each formal level studied was taken as a group response observation and each subject within that formal level studied as a repeated measure of that group observation. Overall, nine observations for all context levels (fA: 3) were evaluated by six different measures of discipline abstract level (fB: 3) and ancillary factor ability level (fC: 2). Subjects within a formal level studied (fD) were randomly assigned to context levels (fA) and attended to tasks only at one of the three context levels. Also, each subject represented only one of the formal studied levels (fD).

The statistical design for the study involving learner perception was a 3x3x2x3 factorial design with repeated measures (Table 3-3) (Appendix I, Figures I-1, I-2, I-11, I-12; Appendix H). Repeated measures analysis of variance was used to analyze the data.

Table 3-3
Factorial design (3x3x2x3) with repeated measures on two factors (fB; fC)

| (fA:)i | (fB: ) j / (fC: )k / (fD:)l | self-eval_mc good | self-eval_mc poor | self-eval_sa good | self-eval_sa poor | unit-eval_sa good | unit-eval_sa poor |
|---|---|---|---|---|---|---|---|
| CL1 | MS | | | | | | |
| | HS | Mijkl | | | | | |
| | HSP | | | | | | |
| CL2 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |
| CL3 | MS | | | | | | |
| | HS | | | | | | |
| | HSP | | | | | | |

The analysis studied the use of three context levels, three learner perception levels, two ancillary ability levels, and three formal studied levels. Factor A (fA: experimental group, i = 1,2,3) consisted of three groups: context level 1 (CL1: control), context level 2 (CL2: treatment 1), and context level 3 (CL3: treatment 2). Factor B (fB: level of learner perception, j = 1,2,3) had three viewpoints (from less difficult to more difficult query): (1)

self-evaluation: multiple choice (self-eval_mc), (2) self-evaluation: short answer (self-eval_sa), and (3) unit-evaluation: short answer (unit-eval_sa). Factor C (fC: level of ancillary ability factor, k = 1,2) consisted of two groups: (1) less than average (poor), and (2) average or greater (good ) for ancillary factor reflecting ability in science and mathematics. Factor D (fD: formal level of concept studied, l = 1,2,3) had three groups: (1) middle school (MS), (2) high school (HS), and (3) high school physics (HSP).

The cell criteria values, Mijkl, for the learner perception factorial matrix were subject responses on the evaluation instruments: self-eval_mc, self-eval_sa, and unit-eval_sa. Each formal level studied was taken as a group response observation and each subject within that formal level studied as a repeated measure of that group observation. Overall, nine observations for all context levels (fA: 3) were evaluated by six different measures of learner viewpoint (fB: 3) and ancillary factor ability level (fC: 2). Subjects within a formal level studied (fD) were randomly assigned to context levels (fA) and attended to tasks only at one of the three context levels. Also, each subject represented only one of the formal studied levels (fD).

Winer (1991) has identified advantages of the repeated measures factorial design on individual subjects (pp. 531-547). This design helps the investigator to picture and group the study variables; several variables can be studied together; prevents alpha from becoming inflated due to multiple student-t's; and interactive effects of independent variables on dependent variables, can be studied. Page (1975) suggested making a unit of students likened to a subject such that the unit is treated as if it were a single subject. Page commented "Then treat the interesting sub-categories within this unit as if they represent repeated measurements of the same subject made under different pseudo-conditions" (p. 342). In a sense "groups" are considered to be "individuals" and measurements of different subgroups are considered as if they were "different conditions" of the same group. Such a statistical design serves to retain statistical rigor for main effects yet "recaptures the richness within the classroom" for interaction effects (p. 342). Page

suggested that such designs provide generalization for a research study by "permitting the transfer of a great deal of sophistication from one setting" (such as repeated measures on an individual subject) "to another setting" (such as different subgroups within the same intact experimental unit) (p. 342).

## Population Demographics

The student population from which the study population was drawn consisted of middle school students, grades six through eight, and high school students, grades nine through twelve enrolled in P.K. Yonge Development Research School, Gainesville, Florida. The demographics of this secondary school population by race, sex, and school level are presented in Table 3-4.

Table 3-4
Demographics for Secondary Student Population Enrolled in P.K.Y. DRS

| | Middle School | High School | HS Physics |
|---|---|---|---|
| White | 121 | 239 | 38 |
| Black | 42 | 104 | 0 |
| Hispanic | 17 | 24 | 1 |
| Other | 7 | 16 | 0 |
| Male | 92 | 197 | 18 |
| Female | 95 | 186 | 21 |

This student population of about 610 secondary students from north central Florida is similar in distribution to student populations enrolled in public junior and senior high schools of Alachua County, Florida. The study population drawn from this secondary school population is described in the next section.

## Study Population

The sample for this study was drawn from the secondary school division of P.K. Yonge Developmental Research School at the University of Florida, Gainesville, Florida.

The subjects were middle school and high school students. Three middle school science classes and four high school classes, three science and one mathematics, were selected into this study on the basis of teacher interest, subject matter, and class schedule.

Each parent of middle and high school students in the seven selected classes were sent a parental consent form that described the procedures that would be used in the data collection. A total of 73 middle school students and 116 high school students responded by returning signed parental consent forms. The resulting study population consisted of a total of 41 middle school males, 31 middle school females, 41 high school males, 31 high school females, 18 high school physics males, and 18 high school physics females. These students were randomly assigned to one of three experimental groups without regard to gender, race, academic ability in science and mathematics, or attitude towards science and mathematics from each of the seven classes. Students within each of these experimental groups were identified for ability level in science and mathematics and divided into good and poor science and mathematics ability level categories. The resulting sample student population as distributed among the three experimental groups is presented in Table 3-5.

Table 3-5
Distribution of Subjects Among the Three Experimental Groups

| | MS | | HS | | HSP | |
|---|---|---|---|---|---|---|
| | p | M/F | p | M/F | p | M/F |
| E1(qA) | 24 | 16/8 | 24 | 15/9 | 12 | 4/8 |
| E2(qB) | 24 | 17/7 | 24 | 12/12 | 12 | 6/6 |
| E3(qC) | 24 | 8/16 | 24 | 14/10 | 12 | 8/4 |
| | 72 | 41/31 | 72 | 41/31 | 36 | 18/18 |

A total of 72 middle school subjects, 72 high school subjects, and 36 physics high school subjects participated in the study. Middle school students randomly selected into the three experimental groups distributed such that 24 were in experimental group 1 (control), 24 were in experimental group 2 (treatment 1), and 24 were in experimental group 3

(treatment 2). High school students randomly selected into the three experimental groups distributed such that 24 were in experimental group 1 (control), 24 were in experimental group 2 (treatment 1), and 24 were in experimental group 3 (treatment 2). Physics High school students randomly selected into the three experimental groups distributed such that 12 were in experimental group 1 (control), 12 were in experimental group 2 (treatment 1), and 12 were in experimental group 3 (treatment 2) (Appendix F).

## Procedure

Students from secondary classes in science and mathematics were randomly selected into three experimental groups. The three experimental groups correlated with three laboratory quads having four work stations each, all prepared with a task progression of activities on force and motion. The instructional task activities presented to each of the three experimental groups differed on context; that is they were designed for a specific context level. Context-based task activities were controlled such that manipulative control and scenes and events present in electronic animated simulations used at the three workstation quads ranged from being less diverse and definitive to being more diverse and definitive in representing visual imagery emulating real world situations and for instances (Appendices C, D, E).

Workstations within each of the three quads were grouped on context level associated with the instructional task activities. Each of the three quads provided a different level of contextually illustrated instructional materials on concepts in force and motion. Imagery representations presented at each of the four workstations of a given quad were replicated and all students attending workstations specific to a quad used identical instructional task activities based on the context level assigned to that quad. However, the type of force and motion investigative activities and their sequence as well as the number of activities remained constant at each workstation in all three quads throughout the study.

The instructional task activities used in the study were delivered through innovative, multi-modal, computer-based technology supporting hands-on, interactive, multimedia

learning environments. Each set of task activities was supported with activity worksheets providing students with directed assistance reading text, DART, and soliciting feedback to open form queries regarding the task at hand (Appendix G). Assessment instruments used in the study were replicated at each of the four quad workstations for all three quads such that each student in the study received the same set of assessment instruments: pre, post, checkpoints, attitude survey, self-evaluation, and critique of overall study (Appendices K, L). All workstations were supported through connectivity to a high-speed network system facilitating workstation preparation with assessment and treatment software, monitoring of student activities, and collection of data from computer assessment instruments. This investigator assisted each teacher with workstation setup, management of hardware and software, student workstation interface, and acted as a guide on the side during the treatment implementation phase of the study.

## Experiment

The instructional setting and the experimental design are discussed in this section. The instructional strategy and context criteria are discussed in the next chapter, Chapter 4, and describe the implementation of the CRS learning models utilized in the laboratory-classroom learning environment.

### Instructional Setting

The study was conducted in a science laboratory setting of a recently constructed technology enhanced state of the art science learning center. The science learning center laboratory contained three quads; each equipped with four state of the art Macintosh computer workstations. Each workstation monitor is positioned so as to be central to a wide u-shaped spacious counter wraparound; each workstation computer and other media technology peripherals are positioned on cabinet shelves located under the countertop. The wide wraparound counter space provides room for group work and experimentation in a way that helps students focus on their task assignments at that workstation (Appendix C).

This laboratory setting allowed the researcher to study student behavior under conditions in which students were more in control of the systems they were investigating. This setting also suggested a more relaxed atmosphere for active collaborative learning opportunities within quad workstation groups as contrasted to the typical environment of a more traditional classroom setting. Emphasis was on a systems approach to problem solving and allowed for open-ended investigations with the instructional materials presented.

**Experimental Design**

Secondary students attending P. K. Yonge DRS were randomly selected without regard to gender, race, academic ability or attitude towards science, mathematics or society into one of three quads. Each of the three quads provided a different level of contextually illustrated instructional materials on concepts in force and motion. Each quad consisted of four workstations and all four workstations within a quad utilized exact replications of the instructional materials specific to that quad. That is the experimental setting consisted of three quads with four workstations at each quad. One quad was used as the control group for the investigative study and each of the other two quads as the two experimental groups in the study. Hence, this investigative study had one control group and two experimental groups, each of the experimental groups differed from each other and the control group only in the level of the contextual referent systems utilized through the instructional strategy to develop concepts on force and motion (Appendix C).

The level of contextual referent systems was varied at appropriate points within the task progression of activities by increasing the diversity of contextual referent systems presented to the learners across treatment groups while keeping the number of contextual referent systems presented the same for all treatment groups (Appendices D, E). Hence contextual referent systems for instructional tasks targeted to the control group were less varied and more random in nature than contextual referent systems for instructional tasks presented to the two experimental groups when developing concepts on force and motion.

The two experimental groups were likewise divided only by level of context; one with a context level that was twice that of the other. Further, the context level for the experimental group receiving the lower context level for the two experimental groups was twice the level presented to the control group. Again, the level of context for the selected instructional materials presented to the three groups studied was differentiated only in the diversity and clarity of visual information. This was provided by the context based visual images used as for instances and associated with force and motion concepts aligned with materials selected for each of the three study groups in the task progression of activities during the instructional delivery stage of this investigative study.

Again, the experimental groups are identified as students attending workstations in quad A being the control group and students attending workstations in quad B and quad C being the two experimental groups. The experimental group assigned to quad C received a selection of instructional materials at a higher context level than that given to the experimental group assigned to quad B. However, all students participating in the study received the same number and order of instructional task progression activities on concepts in force and motion.

The study sample population is also divided into three distinct groups as identified by level of formal education in science and mathematics. Students are assigned into education level groups on the basis of being a middle school student, a high school student not having had physics or a high school physics student. The middle school students, novice learners, represent the subset of the population who have limited experience with the usage of formal cognitive thought processes useful for solving problems in science. The high school students, intermediate learners, represent the subset of the population who have developed more formal cognitive thought processes for solving science problems. The physics students, local expert learners, represent a subset of the high school population who have received formal instruction for developing force and motion concepts. Students from each of these population subsets were distributed over all experimental groups and

were presented with all instructional task activities specific to the experimental group in which they were assigned (Appendix F).

Additionally, students within each treatment group were divided into two subgroups identified by ability level in science and mathematics. Data to determine ability level was obtained from the school's records on student academic achievement in science and mathematics courses. One subgroup identifies students below average ability level (poor subgroup) and the other identifies students of average ability level or greater (good subgroup). Ability level is used as a control factor in the study design for investigating the context effect due to an expected interaction of ability level with context level. Students of low ability level may perform better on activities presented at a higher context level than on activities presented at a lower context level. Activities presented at a lower context level may benefit both students of low and high ability. Grouping students on science and mathematics ability level makes the study sensitive to student ability level from low to high within a learner sub-population type and across learner sub-population types for which learners vary in their formal mastery of force and motion concepts.

Individual differences among learners due to ability level in science and mathematics was accounted by the statistical model applied to data, since the investigator was not able to control for students being self-selected into the study at different points in time prior to being randomly assigned into an experimental group. Hence, student scores within each subset of the population were adjusted to account for individual differences due to ability level as identified by an ability level index developed for this study describing student achievement in science and mathematics courses on a continuum from low to high.

# CHAPTER 4
# IMPLEMENTING THE CRS LEARNING MODEL

## Overview

The instructional strategy model applied to this investigative model involved an immersion of the learner in a progression of tasks focused on experiential development of concepts on force and motion. This investigator utilized instructional resources in a schema that provided opportunity to focus and build on basic force and motion concepts. One objective for selected resources was that they help the learner acquire a feeling for working with measurable parameters used to quantify time, space, matter, position, rate, and direction. Another objective for selection of these resources was that they involve the learner in the usage of measurable parameters in an experiential way that allows the learner to control, modify, adjust, predict parameter values for physical systems that respond dynamically as such changes are applied to the test system (Appendix C, Figure C-6 and Figure C-7; Appendices D, E).

As the learner becomes engaged and immersed more deeply in experiential activities involving these basic concepts of space, matter, time and movement, higher order concepts begin to evolve almost naturally in the learner's subconscious subset of force and motion concepts. Specifically, the learner begins to relate to events that provide dynamic illustrations of a body's momentum (p, inertia), momentum change ($\Delta p$, impulse), and rate of change of momentum ($\Delta p / \Delta t$, force)--each of these constructs being a combination of the more fundamental basic concepts and being more demanding on the learner's cognitive load. In a real and interchangeable way, the learner builds an interactive perspective of force and motion concepts using well-illustrated examples of inertia, impulse and force through various representations of associated real world events. Hence the learner

discovers reality links for conceptualizing and reasoning about systems involving these force and motion concepts. And these reality links become part of the learner's mental fabric for constructing a conceptual understanding of the perceived real world events.

## CRS Instructional Strategy Models

Models used in this study for the context-based task progression of activities on force and motion are described later in this section. These series of tasks represent a progression not in the sense of less to more things to do and attend to, but in the sense of moving more from a concrete to an abstract situated imagery for facilitating processes of thought development and of fabricating an operant conceptual framework of associated mental imagery on systems of force and motion. This task progression was designed to facilitate student thought patterns for moving from studying more concrete systems of motion to studying more abstract systems of motion. The glue that serves to find connectivity within and between these dynamic models is coined for the purposes of this study as the contextual-imagery referent system, CRS. Hence, the instructional strategy applied to the sample population for the purposes of this investigation is called the CRS Instructional Strategy Model.

An obvious advantage of such a CRS tool is the improved ability to work with human cognition in terms of growth and development at a more fundamental level of an emerging intelligence. The CRS Model can be considered to target habits of the mind conducive to processing information for enhancing desired thought patterns involving, in the case of this study, Newtonian systems of motion. The trend of the task progression is to capture each moment as a portion of a student's mental growth continuum. This lets the investigator study ways learners utilize their experimentation with motion systems in order to reflect more clearly on physical motion phenomena. Since within any population intelligence can be described over a range of capability, likewise the growth of intelligence reflective of a population can be thought of in terms of a range of capabilities. The creation of context levels within the study provided this investigator with the opportunity to capture and study

moments in conceptual growth over a range of student behaviors. As applied to this study, three context levels were identified for each of the task activity sets from less diverse and definitive to more diverse and definitive using contextual-imagery representations supporting the study of a specific system of motion for a given task activity (Appendices D,E). Usage of CRS tools, through the task progression of selected activities, conditions the learner to making needed associations to the tangible world from the more abstracts representations of force and motion concepts. Observing students grouped on context level allowed this investigator to search for context effects, conditions whereby learning becomes more meaningful for the student as a function of structured, relevant, and well-associated instructional resources. Similar studies may be found to correlate strongly with cognition enhancement possibilities for the emerging intelligence.

**Self-Contained Laboratory Model and Tasks (pw)**

The task progression was initiated using guided hands-on real-time laboratory experiments in force and motion that utilized a total self-contained analytical laboratory. This force and motion laboratory involved identifying measurable quantities of a body's position, motion and applied force using sensory force and motion probes; automatic sampling of the raw data; reduction and immediate feedback in a graphical format for analysis; and interpretation by the learner/investigator. The laboratory became the metaphor for hands-on experiential investigations of what-if events and served to focus the learner's mental capacities on interfacing the real world with measurement opportunities and the representation and meaning of those measurements that were presented through immediate and direct display of interrelationships (multiple and varied associations of physical events and the graphical presentation of those events) (Appendix D, Figure D-1; Appendix E, Figure E-1 to Figure E-3).

These experiences served to raise the awareness level of the learners of various kinds of difficulties which they themselves were experiencing and had the opportunity to address as they carried out activities using their own self-contained laboratory system. Simply

interfacing with a system offering opportunities to take control over variables that define how a system functions was in itself a discovery for these students. More than not, the students seemed astounded that a system could be defined in terms of a limited number of measurable and interrelated variables. In particular, the process of extracting meaning from the graphical display representing force and motion event s being studied seemed to pose difficulties for students; but given opportunity for practice through usage of the C-DART sheets (context directed activities reading text) (Appendix G, Figure G-1), show and tell by the teacher (or investigator), and discussion with peers, those difficulties proved not to be insurmountable for most students.

**3-D Star-Field Model and Tasks (sf)**

The self-contained physical laboratory system provided point of entry for the learner into further investigations of problems involving force and motion concepts. Next, students moved beyond the physical laboratory studies to simulated environments within the multimedia computer workstation. Students were first presented with a three-dimensional cubic manipulative containing various star-fields (arrays of pixels representative of a group of stars) and utilized this freely rotating cube to explore selected star-fields from different perspectives. When the cube was set rotating, students observed various visual patterns as the selected star-field turned about in space. This star-field movement allowed students to vary their point of view for the selected star-field, discovering a whole spectrum of images representative of the same star-field but which were not apparent to the observer on first sight of the non-moving star-field. Students viewed with awe the transformation of a star-column representative of the milky way into a disc array as they rotated this star-field a quarter of a turn within its reference frame from an side end view to a top front view. Hence, students associated a progression of images for a given star-field uniquely defined within its frame of reference as a function of the observer's viewpoint. These exercises provided the learner with an immediate sense that pattern observations are variable depending on positional location of a pattern of bodies

within a reference frame and on the viewing direction from which the pattern is observed. This type of activity helps students think beyond the apparent visual pattern representation for a body by providing a way to discover other possible representations within the continuum of a system using a progression of visual images each representing the same system (Appendix D, Figure D-2; Appendix E, Figure E-4 to Figure E-6; Appendix G, Figure G-2).

**A Body in Motion: Force-Field Model and Tasks (mb)**

An operational and focused sense of the space-position relationship within the context of a reference frame for a body under study and from the observer's viewpoint is needed for students to picture force and motion events in a critical and analytical way. The space-position-time relationship of a body presents a more complex challenge to the learner's observational skills and requires special effort to overcome learner difficulties that emerge from investigations on space-position-time relationships involving a moving body. The learning task selected to interface students with moving bodies within a reference system utilized a dynamic modeling building activity through which students select a system of gravitational bodies, set this system into motion and observe the path of the various bodies played out over time as defined by the laws of force and motion for orbiting bodies. Next, students define their own gravitational system by identifying the number of bodies present, the mass of each body, and their relative starting positions and velocities within a reference frame when the system is first set into motion.

Students were intrigued with the opportunity to observe the motion of several bodies at once relative to one another as their pattern of tracks was played out over time. They began to freely enter into what-if scenarios, wonder about postulated outcomes by making adjustments to mass, position and relative speed of a group of orbiting bodies, and then test out their suppositions finding out what in fact happens with these orbiting bodies over time. Students literally became magnetized to this activity, designing and playing with a variety of universe designs to determine whether or not if the observed outcomes in fact

aligned with their various proposed what-ifs. Students would try out their innovations and later predict, modify and try again (Appendix D, Figure D-3; Appendix E, Figure E-7 to E-8; Appendix G, Figure G-3).

The dynamic universe modeling tool was fantastic in the way it aroused student curiosity about bodies in motion, grabbed student attention and focused and involved students in a way that gave each student a sense of operational control over the variables defining a system of moving bodies. As had occurred during the activities using the self-contained analytical laboratory to study systems of force and motion, once more students became engaged in making strong associations among moving bodies with variables defining specific matter and space-position-time properties for those moving bodies and with the observed change in values of the variables associated with specific moving bodies over a continuum in time. This universe modeling system provided the stage for building strength of relationships on concepts of force and motion by the use of strongly associated contextual referent systems of moving bodies modeled within dynamic gravitational systems and prompted the emergence of powerful ideas related to force and motion from the learners themselves. Almost intuitively the students seemed to discover the interaction of gravity between bodies as a mass-distance relationship, and hence acquired, in a relative short time span, an operational understanding of the gravity effect on bodies in motion that may have been unclear prior to this activity.

**A Body in Motion: Reality-Link Model and Tasks (rw)**

The next series of activities in the task progression used for the development of force and motion concepts engaged the students in cartoon facsimiles of simulated events associated with real world contextual settings. Each simulation provided opportunity for the student to control selected variables over an allowed range of values in order to define initial starting conditions for a force and motion event and then to make observations of the event and its outcome as the event was played out over time. The selected simulated events provided an opportunity for the student to interactively make connections between concepts

on force and motion and surrealistic real world events occurring in a variety of well illustrated dynamically worked-out problems by controlling initial values for specific system variables which then defined the sequence of events that followed. A direct cause and effect relationship was apparent to the learners as they adjusted values of the controlling variables in anticipation of modifying an event outcome by causing a cartoon body to accomplish some task like safely jumping a canyon or parachuting to the ground. The simulated dynamic events included an overlay of symbolic vector elements that reinforced associations being made by the student between the events that occurred and underlying concepts relating to the type of applied force, the strength and duration of the applied force, and the kinds and extent of motion that occurred for some body in motion. Illustrating symbolic elements dynamically during cartoon events helps the learner bridge various real world events involving force and motion with abstract representations used to model relevant concepts about force and motion being illustrated by those events (Appendix D, Figure D-4; Appendix E, Figure E-10 to E-12; Appendix G, Figure G-4).

**A Body In Motion: Human-Flight Model and Tasks (ft)**

A final series of activities in the task progression used for the development of force and motion concepts launched the student on a surrealistic journey in a hang glider flight over a vast valley. Using human free flight as the contextual referent, students were invited to explore concepts on force and motion in more depth and at a more formal level of presentation. Well defined multimedia pictures and clips portrayed various stages of the launch and flight and scenes were overlaid with symbolic vector elements in an attempt to guide the learner towards making more focused observations and associations between various facets of the flight events and related force and motion concepts. The hang glider metaphor provided a stage on which to help the learner focus, relate, and examine where forces act, what causes the launch, and what sustains the flight along the path of motion. Impulse was associated with the momentum change needed for launch; inertia was related to a sense of constant momentum during the experience of sustained horizontal flight across

the valley below; and loss of altitude was related to a sense of rate of change of momentum resulting in a gradual descent flight under a constant gravity field towards the ground. A multimedia matching exercise challenged students to make connections between the symbolic terms used for momentum, momentum change and rate of change of momentum with brief textual definition counterparts for these terms. Matching exercises were supported with hypermedia clues that provided students opportunity to revisit a myriad of enhanced context-based, well-illustrated and dynamic array of associated multimedia imagery that targeted the force and motion concepts under study (Appendix D, Figure D-5; Appendix E, Figure E-13 to Figure E-15; Appendix G, Figure G-5 to Figure G-14).

### Context Level Criteria

This study seeks to understand and model the effect that encouraging diverse contextual associations in developing integrated concepts has on student understand of an underlying unifying conceptual theme, namely Newtonian systems of motion. The context effect, the main factor investigated in the experimental phase of this study, concerns whether or not the instructional effectiveness of teaching Newton's laws of motion (momentum, momentum change, and rate of change of momentum) can be expedited by providing the learner with opportunities to interact with real world applications of these laws under similar but different contextual settings. The experimental design was constructed to be sensitive to a context effect in a way that tracked student ability to apply concepts to related but different applications of problems and problem solving in real world situations. The context effect was studied on a continuum from less to more by identifying context-based instructional resource materials on force and motion systems at three levels of context-based imagery. The context effect looks at differences in student profile based on context level of imagery information available to the student during a task progression of instructional activities on force and motion concepts and systems. Again, the experimental design for this study was constructed to be sensitive to the context effect: the differences

that more varied and meaningful and less varied and meaningful contextual learning experiences create on the learning of Newton's laws of motion.

Instructional task activities used in this study were prepared on three context levels which were then equated to three experimental groups: two treatment and one control. Context-based activities were identified for each set of task activities and context level criteria were applied in assigning task activities grouped on context level to each of the three experimental groups. The task progression of activities included a self-contained analytical laboratory model, a star-field visual perception model, a force-field model building model, a reality link parameter control model, and a human-powered flight model. An example of applying the context level criteria to the self-contained laboratory model illustrates the way in which the context criteria allowed this investigator to discriminate each of the three experimental groups on context level.

**Self-Contained Laboratory Model Context Level Criteria**

The laboratory model provided all students with a hands-on scientific laboratory system using sensory force and motion probeware interfaced with graphing calculators for the real-time collection of raw data, conversion to reduced data and presentation in graphical form in a way that the immediacy, ease and replication of the response variables facilitates the connection of a real world event with definable and measurable variables useful in scientific investigations and represents the behavior of those variables within the framework of a set of values as being represented in a continuum through abstract visualization tools such as the continuous trend on a graph.

Hands-on laboratory activities at quad A, the experimental control group workstation setting, were selected to be more mono-contextual in nature investigating force and motion concepts using traditional manipulative props for linear movement of an object on a level surface and on an inclined plane but providing for a way to vary the mass of the object in motion. Observations of the moving body were obtained separately using a force sensor and then a motion sensor for each of the systems under study, level surface and inclined

plane and again with increasing mass loads of the moving body. Students were asked to report on the data patterns and discuss the integration of the observed events in terms of force and motion (Appendix E, Figure E-1).

Hands-on lab activities at quad B, the experimental treatment 1 workstation setting, were selected to provide a limited extension into multi-contextual representations of similar but different problem situations dealing with force and motion concepts. Activities at quad B broke away from the more traditional metaphor of block and inclined plane, Galileo's gravity filter, for studying a body in motion and moved on to observations involving various types of oscillations of a body in motion. At quad B activities for studying a body in motion included spring type oscillations involving dual response from force and motion sensor used to track the event, pendulum type repetitive movements in two different planes relative to the motion sensor. Students were asked to interpret and compare data taken from the various body-in-motion studies. When students ran the pendulum type activity under different software programs for plotting data obtained for a body in motion, students were asked to explain why differences occurred between the two plots (Appendix E, Figure E-2).

Hands-on lab activities at quad C, the experimental treatment 2 workstation setting, were selected to be more intellectually challenging over the types of activities performed at quads A and B for studying force and motion concepts. Students at quad C used the pendulum as a focus for studying a body in motion as discussed for activities in quad B. Additionally, students at quad C were also presented with two additional think type activities involving the nature of forces and the motion of bodies. One activity focused on a piston under the control of the student which was moved in a closed chamber filled with air and asked to interpret the behavior of observed applied force as associated with the recorded chamber pressure in terms of the observed position of the piston which was graphically displayed as a linear relationship after calibration of the system and collection of the data. Another activity challenged the student to invent a way for measuring an invisible

force posed by a floating magnet suspended through a vertical rod on top of another magnet (Appendix E, Figure E-3).

Summarizing the application of context level criteria to the laboratory model, context-based activities were selected such that the cognitive load at quad B was more varied in context-base, more multi-contextual, over that in quad A allowing for about twice as many different types of manipulative activities targeting force and motion concepts. The cognitive load at quad C was more varied in context base, more multi-contextual, over that in quad B again allowing for about twice as many different types of manipulative activities related to concepts in force and motion. The underlying theme of investigations into force and motion concepts of moving and non-moving bodies was the same at each of the three quads, the same number of activities were presented to the learners at each of the three quads for the same total time of performing the selected tasks investigating concepts in force and motion using the same force and motion sensors. However, the usage of similar but different tools and challenges with force and motion sensors identified the context level for the laboratory system implemented at quad A, B, or C corresponding to experimental group, control, treatment 1, treatment 2, in the manner described above.

**Inquiry-Based Simulation Models Context Level Criteria**

Context level criteria were applied to the inquiry-based simulation models. Criteria applied to the star-field model, force-field model and real world parameter model resulted in selected simulations for each of these models being distributed on context level over quads A, B, and C. Simulations for each of these models that were presented at each quad are identified in Appendix E (Figure E-4 to Figure E-12). While discriminating on context level, each simulation model provided similar inquiry opportunities among the three quad workstation groups. These interactive simulations allowed students to manipulate star fields in three dimensions, to study orbiting gravitational bodies under different conditions of initial mass and velocity as well as design and test their own universe; and to test various real world animated force and motion simulations by trial and error as the system test

parameters were varied. This three-dimensional tool helped the student towards building multiple perspectives of a problem utilizing different ways for looking at the same system.

**Human-Flight Model Context Level Criteria**

Context level criteria applied to the human flight model were done in a different but related manner. The surrealistic hang glider flight related a high interest topic to the human involvement in force and motion concepts. As the human became the moving body launched into free flight, force and motion concepts were illustrated in terms of the hang glider person whom the learner subconsciously related back to the learner's own self. This same scenario was presented to students at all quads. The scenario ended in a culminating activity in which the students were challenged to match symbols representing various force and motion concepts with the appropriate concept. This activity differed for each of the quads in that although learners at all quad workstations were presented with the same total number of clues, students at quad A received more text-based clues in support of the concept matching exercise while students at quads B and C received far fewer text-based clues but an increasing number of well-illustrated visual clues. The visual imagery clues included multicontextual pictures and short clips having extended and enhanced representations of the concepts used in the concept matching exercise.

Again, common elements for the human flight model were present at each of the quad workstation groups. The human flight field trip tutorial applied concepts of force and motion to free flight, made use of color, labeling and pointers to provide ways for visualizing where forces act, and dynamically illustrated momentum and impulse concepts in terms of the hang glider's movements. Also, checkpoints within this flight tutorial provided opportunities for students to revisit and extend force and motion concepts (Appendix E, Figure E-13 to Figure E-15).

Discriminating on context level among force and motion activities presented through the quad-based workstations, this investigator selected activities representative of being more diverse and multicontextual for activities presented at quads B and C than the same

number of similar activities presented at quad A. And activities presented at quad C were more diverse and multicontextual than those at quad B. Hence the context level increased from quad A to quad B to quad C. Quad B had about twice as many different context-based activities as quad A. And quad C had again twice as many different activities as quad B, or about four times as many different context-based activities as presented at quad A. The total number of context-based activities on force and motion was the same for all workstations at quads A, B and C.

## Empirical Knowing-Model

The study of human cognition, mental abilities, and thinking processes is only beginning to take form and provide guided insight into the thin and delicate fabric of knowing and thinking. The knowing model design for studies using learner populations similar to that used in this study is at best a crude representation of what scientists have known for sometime, but have only recently directed efforts towards modeling populations of learners in this way. The knowing model described in this section and designed for the kinds of sample population data collected in this study may be considered innovative cognitive model. The basis for this model has emerged from having probed a diverse population of learners using the context effect. The investigator regards the context effect as a dominant factor in probing for the development of the free association of ideas relevant to the conceptual content under study by the learners (Appendix N).

The context effect provides the investigator with the opportunity for characterizing a diverse population on a few selected underlying indices that serve to identify and characterize the learner's state of knowing and the momentum that propels the learner forward along the path of knowing. Five indices characterize this knowing model.

1. Ability index is a measure of the learner's achievement and depth of focus within a field of study.
2. Attitude index is a measure of the learner's feelings towards a field of science and other related fields of science.

3. Believability index is a measure of the tenacity by which concepts of an underlying theme are held by the learner and the degree to which they seem structured within the learner's mental imagery systems.
4. Expertise index is a measure of the learner's mastery of concepts, both operational and intuitive levels for functioning within some field of study.
5. Control index is a measure that identifies the degree of self-activation the learner has in becoming involved and carrying out a task.

Using data collected during this study, all five indices for the empirical knowing model have been scored to some limited degree for the target study population. This model offers researchers and practitioners a tool that lets one sculpt, shape, and model learner capability within selected fields of study. Used appropriately, the model may suggest possible opportunities for extending the human knowledge bank beyond its seemingly current limits as well as enhancing the learners' capacities for knowing.

A three-indices knowing model can be visualized on a three-axes coordinate reference frame assigning the ability index to the x-axis, the believability index to the y-axis, and the expertise index to the z-axis (Appendix N, Figure N-2). A knowing model having n-indices can similarly be collapsed into three-dimensional space by aggregating closely associated indices into one index. One might suggest an expectation index from a combination of the attitude and believability indices, or one might extend the expertise index to include the control index. Another study design may suggest combining the believability and expertise indices into a composite knowledge-belief index and the attitude and control indices into locus of control index. Using indices aligned on axes defining an n-dimensional space, researchers may become more precision tuned at investigating the thought processes by which learners make use of hypermedia instructional delivery type tools for concept development within a field of study and thereby facilitate their construction of domain specific knowledge structures. Considering the array of innovative tools having infinite resource reservoirs together with speedy response times that are fast

entering the classroom arena, this knowing-model may help to fill a gap in current cognitive research tools. The next step is to describe the manner in which the identified knowing-model indices can be constructed.

The ability index could be constructed from student records of achievement in science and mathematics; the index would combine the type and number of science and mathematics courses taken within a secondary school's upper (9-12) and lower (6-8) grade levels (basic and remedial as opposed to advanced) with the performance of the student in science and mathematics as identified by the student's combined grade point average in science and mathematics.

The expertise index could be constructed by comparing the correctness of learner response on the pre to response for the same concept question on the post after receiving treatment as defined by one of the three possible context levels. Learner response might be scored on a continuum for the correctness of response from pre to post questions focused on concepts in momentum, momentum change and rate of change in momentum of a body in motion or at rest. This continuum might utilize a gradient scale from 0 to 6, with 6 being most correct and 0 being least correct.

The believability index could be constructed in terms of a shift effect from the tendency of the learner to move towards or away from the correct response from pre to post on the same concept question. Learner response might be scored for the tenacity by which the learner held to the original choice if correct or exhibited movement towards the correct response. Again this would be over a continuum score range from pre to post questions focused on concepts in momentum, momentum change and rate of change in momentum of a body in motion or at rest. And this continuum might utilize a gradient scale from 0 to 4, with 4 being highly convinced of having made the correct choice and 0 being clueless as to whether or not the correct choice was made on a gradient scale from 0 to 4.

Both the expertise and the believability indices presuppose that the learner has completed a progression of carefully designed and focused tasks emphasizing experiential

knowledge structures and representations for conceptual development of some content area. A knowing-model can be crafted out of n-dimensional space by the researcher and then used in an empirical way to study a target population similar to that from which the data was collected to construct the model. The spatial representation of the knowing-model can be applied to a typical learner at specific stages of mastery and used to visualize and approximate a learner's state of knowing.

The knowing-model itself depends on referent points within its structure in order to capture the range and kinds of learners present in any given population to which it might apply. This means that some sort of upper and lower limits need to be identified which can be utilized in locating typical learners from within other similar populations of learners. This study was designed to allow for identifying to some degree two anchor points: a lower anchor point and an upper anchor point. The lower anchor point on all three indices is obtained from data collected from middle school students participating in the study and who provided the sense of a naive control locus for the model. The upper anchor point on all three indices is obtained from physics students participating in the study and who provided the sense of an expert control locus for the model. Also, this expert group was utilized as sort of an internal standard or control for the criterion measurement instruments in that the expert response to each query item of the various instruments was taken as the favorable response regardless of the agree-disagree paradigm that was present in the survey type query items and as the correct response in the content type query items.

In general, the sample of high school students not having taken a physics course are located on gradient scales for the indices somewhere between the high and low anchor points using performance data collected before, during and after treatment and using student's achievement in science and mathematics data present in school records. Hence, data collected through the instructional treatment can be processed back through the knowing model, sculpting a better picture of what the learner knows and what the learner

needs to know next along the journey of conceptual change towards mastery, grasping concepts in the way that experts tend to think about those concepts.

Identifying where the learner falls within this ability-belief-expert, "ABE" space (or GOM-sphere: galaxy of the mind sphere) helps to better characterize learning difficulties specific to a learner or a group of learners typical of the population which the model empirically represents. Such a knowing-model suggests a basis for formulating precision instruction opportunities for learners by selection of instructional strategies which would have greater impact because the strategies focus more directly on the specific difficulties the learner exhibits in understanding a concept. Also, participants in the instructional process can be made more aware of an individual learner's difficulties and have the opportunity to examine those difficulties in reference to a criterion scale that more clearly identifies where the individual learner falls in relation to specific goals identified for concept mastery and that have been achieved by peer students or students of similar abilities. This type of model just might influence formal learning in a way that reinforces a 'can do' attitude and stimulates the learner to take on a renewed willingness to learn and to accomplish tasks critical to the learning process.

Suppose what in fact might be reaped from such an exotically conceived tool as a knowing-model. Consider the degree to which a model of this type is plastic, able to be rendered and impregnated with various information domains. Such an empirically defined learner-centered knowing-model, when combined with instructional strategy models utilizing customized contextual-imagery referent systems, becomes learner-empowered. The knowing-model suggests a learner active and enabling framework that can be applied to other knowledge domains for any number of formal and informal disciplines founded on the development of abstract knowledge structures within the learner's mental referent system. This abstraction capability comes with various degrees of difficulty for different learner levels, novice to intermediate to expert. The ability to extract meaningful concepts and carryout the connectivity of ideas in a way that the learner is able

to logically integrate new information into pre-existing initial knowledge structures tends to be an easier task for the more experiential learner.

Ways are needed to power the learner's mental exercises; ways to help the learner put into play libraries of different kinds of knowledge referent systems using context-learning focused instructional strategies. During these processes and stages of awareness and involvement, the learner entertains various conceptual changes and progress in a level of understanding from that of a beginner to that of an expert. Imagine motivated learners using imagery tools to relay information through one associative set of ideas back and forth and then launching out into whole new branches of information and opportunities for discovery. Helping learners understand, try out, and utilize the power of contextual-imagery referent systems may be an idea worth pursuing; one that cognitive and educational researchers have been trying to identify for a good portion of this century; and one that just might be called upon by learners and researchers alike to propel the science of knowing into the third millennium!

### MetaModel Summary

This investigator has taken a constructivist, metamodel, and context-based instructional approach in designing a study on experiential learning. This study has potential for enabling a learner's capability for growing mental imagery referent systems about force and motion concepts formally studied that would be more in agreement with scientific principles. Physics education research communities view difficulties students seem to have understanding basic physical science concepts as a cognitive problem that becomes a stumbling block for successful academic achievement within domain specific knowledge disciplines like physics.

This investigative study identifies, sculpts and applies several innovative tools useful for conducting educational research studies that address difficulties students have using cognition to formulate correct representations of the natural world within their own knowledge structures. Descriptions of these tools are given in the following list:

1. Usage of context level as the main experimental factor and of the "context effect" as a measurable criterion variable for investigating learner's concept development in a content area is presented as a research tool.
2. Demonstration of powerful CRS instructional strategies for investigating learning behaviors using new technologies is presented as research methodology.
3. Construction of a "knowing model" using indices computed from experimental group data for visualizing a learner's relevant spatial positioning on three-dimensional gradient scales having a novice-intermediate-expert paradigm was used to promote visualization of the learning growth process.
4. Usage of a statistical model design for studying the context effect provided direction for the study's implementation.
5. Usage of statistical modeling as a research engine which cycles experimental data into the "knowing model" and sculpts the learner's state of knowing has been mentored for future research directions.

The dynamics of these models in different planes of involvement of the learner and researcher are such that the knowing model is at the apex for both learner and researcher; the statistical model provides the engine that moves the data streams from the investigative study into the knowledge model to generate relationship positions among learners at different levels of knowing; and the CRS instructional strategy model provides leverage and control of the treatment needed to deliver content information within context to the experimental study groups of learners. Hence in a real sense the CRS instructional strategy model has been designed to allow the researcher to test out the knowing model while engaging learners in powerful investigative strategies for learning concepts on force and motion. Both the empirical knowing model and the experiential CRS instructional strategy model are extendible to other disciplines requiring development of abstract knowledge structures that poise difficulties for meaningful learning.

# CHAPTER 5
# DATA ANALYSIS AND RESULTS

The purpose of this study was to design a model to study the cognitive and affective behavior of a study population of learners engaged in experiential multimedia activities on force and motion systems in a technology supported environment. This design model tested the study hypothesis in null form using force and motion multi-contextual physics activities with a study population of secondary school students. This design model studied the effect of CRS Dose level (CRS = contextual-imagery referent systems) and challenge level (problem difficulty level) on a study population of homogeneous groups of learners. The design model identified and was sensitive to a number of research effects, including a context effect, a difficulty effect, a technology effect, a learner growth effect, and a learner type effect. All effects were measured in terms of referent local expert responses from a homogeneous group of physics students at each CRS Dose level. These physics students had already studied force and motion systems in a formal physics course and served as an internal reference standard for responses to all measures used in the study.

The conceptual design model for studying multi-contextual learning systems using momentum, as understood from the context of physics, was applied to a study population across diverse homogeneous groups of secondary school learners. The model studied good and poor learners of science and mathematics in terms of learner growth from novice to intermediate to expert (NIE) at different challenge levels of problem difficulty and on different aspects of learners' expectations measured at discrete CRS dose levels. The design parameters allowed for discussing several plausible effects that grew out of the study population. The effects investigated include a "context effect" in terms of CRS dosing; an overall "tech effect" in terms of treatment – no treatment on learner performance

(knowledge) and learner perspective (belief); a challenge effect in terms of effort required by increasing the problem difficulty level; a growth effect in terms of formal level studied (EIN); a learner success effect in terms of good – poor learner of science and mathematics; and a non-response effect in terms of the presence of a trinomial learner response paradigm and as a plausible indicator for monitoring student performance gaps in science and mathematics. (Glonek (1999) has described a non-ignorable non-response in data.)

The collected data were analyzed using a variety of modeling tools. The models allowed for a statistic for hypothesis testing and helped to build an effect profile from which to illuminate a particular effect under investigation. The data were analyzed with repeated measure analysis of variance in addition to linear, exponential, and logistic regression models for multi-variable learner growth and learning domain correlation plots. The study population was examined using both a cross-sectional analysis and a spatial-temporal analysis of the diverse homogeneous learner subgroups of the study population as support designs for hypothesis testing. The relevant statistics are presented in ANOVA and regression summary tables. In addition, descriptive statistics are included for significant interactions and results.

The definition of CRS Dose is restated for clarity of usage in the null hypothesis statements. CRS Dose is abbreviated for contextual-imagery referent system dosage. CRS Dose identifies the level (from low to high) of technology based context-rich reality linked viewpoints present in learning activities with the degree of interactive, multiple, diverse and definitive visual cues presented as enhanced supporting information and integrated into learning activities on force and motion concepts. CRS Dose is associated with the strength of the reality link that experiential learning activities on force and motion systems make to plausible real world experiences. CRS Dosage is the control variable for this research study on learning theory. Fixed levels of CRS Dose (from low to high) were implemented in this study and identified as treatment levels A (1x), B (2x), and C (4x). That is A, B, and C represent three experimental units such that $A < B < C$ and A serves as the base

control unit for units B and C. All research subjects were members of an experimental unit; each subject received a fixed CRS Dose at only one of the three treatment levels (A, B, or C) (Appendix C, Figure C-1).

## Hypothesis Testing and Results

The research findings are grouped into four categories that identify REAL science tech-models for growing analytical caring minds (ACM) using contextual-imagery referent systems (CRS) (Appendix B, Figure B-1):

(a) cluster A: visual tools for inspiring analysis (VTIA-1),

(b) cluster B: identifying with diverse learner groups (IDLG),

(c) cluster C: visual tools for improving attitudes (VTIA-2),

(d) cluster D: nurturing a progression of learners toward success (NPLS).

**Cluster A: Visual Tools for Inspiring Analysis (VTIA-1)**

Does a context effect exist?

**Hypothesis 1: multicontextual**

Ho: Learners of science and mathematics, referenced to an expert response, exhibited no significant difference in their abilities to solve momentum type force and motion problems after receiving a fixed CRS Dose level (A, B, or C) of experiential learning activities on concepts about momentum in force and motion systems.

The computed F value for learner success from pre to post on a written problem set about force and motion concepts was 14.06 at df=1 (Table 5-1); and on an electronic problem set was 0.19 at df=1 (Table 5-2). An interaction of an electronic problem set with CRS dose produced an F value of 3.15 at df=2 (Table 5-2). The F value for less difficult electronic set by time was 13.92 at df=1 (Table 5-3); for more difficult electronic set was 8.52 at df=1 (Table 5-4). The F ratios 14.06, 3.15, 13.92, 8.52 are significant at $p<0.05$. Therefore this null hypothesis was not accepted for the study population.

The means and standard deviations for time by CRS dose are presented in Table 5-5 or the written problem set; Table 5-6 for the electronic problem set; Table 5-7 for the less difficult electronic set; Table 5-8 for the more difficult electronic set. Time and CRS dose interactions are plotted in Figures 5-1, 5-2, 5-3, 5-4 for the written, electronic, less difficult electronic, more difficult electronic problem sets.

Learner overall success on problems about force and motion systems seemed to indicate a significant difference between learner success on the written problem set pre to post for all levels of CRS dose. However, the electronic problem set indicated a significant change for lower and higher CRS dose levels but not moderate CRS dose with performance dropping for lower CRS dose while rising for higher CRS dose. The electronic set was further studied as a function of problem challenge level from less to more difficult. The less difficult set indicated a significant rise in scores from pre to post for moderate to higher CRS dose levels but only slight increase for lower CRS dose; the moderate and higher dose levels scored higher than the lower dose level on the post but not the pre. The more difficult set indicated a significant drop in scores for the lower to moderate CRS dose levels and a slight drop for the higher CRS dose; response was disordinal on pre and post in that the lower dose level performed better than the moderate dose level and the moderate level better than the higher dose level.

Table 5-1
Source Table of Analysis of Variance of CRS Dose for
Force and Motion Problems: Written Problem Set by Time

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 3.80 | 2 | 1.90 | 0.74 | 0.17 |
| Subject(Group) | 363.98 | 141 | 2.58 | | |
| Time | 11.68 | 1 | 11.68 | 14.06 * | 0.98 |
| Time X CRS Dose | 0.17 | 2 | 0.09 | 0.10 | 0.07 |
| Time X Subject(Group) | 117.15 | 141 | 0.83 | | |

* Significant at $p<.05$

Table 5-2
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: Combined Problem Set by Time

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 6.40 | 2 | 3.20 | 1.73 | 0.35 |
| Subject(Group) | 261.08 | 141 | 1.85 | | |
| Time | 0.08 | 1 | 0.08 | 0.19 | 0.07 |
| Time X CRS Dose | 2.51 | 2 | 1.26 | 3.15 * | 0.59 |
| Time X Subject(Group) | 56.17 | 141 | 0.40 | | |

* Significant at p<.05

Table 5-3
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: Less Difficult Problem Set by Time

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 0.49 | 2 | 0.25 | 0.10 | 0.07 |
| Subject(Group) | 344.37 | 141 | 2.44 | | |
| Time | 11.27 | 1 | 10.27 | 13.92 * | 0.98 |
| Time X CRS Dose | 3.87 | 2 | 1.93 | 2.62 | 0.50 |
| Time X Subject(Group) | 104.02 | 141 | 0.74 | | |

* Significant at p<.05

Table 5-4
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: More Difficult Problem Set by Time

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 27.46 | 2 | 13.73 | 3.04 * | 0.57 |
| Subject(Group) | 637.59 | 141 | 4.52 | | |
| Time | 7.03 | 1 | 7.03 | 8.52 * | 0.98 |
| Time X CRS Dose | 2.05 | 2 | 1.03 | 1.24 | 0.26 |
| Time X Subject(Group) | 116.33 | 141 | 0.83 | | |

* Significant at p<.05

Table 5-5
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose: Written Problem Set x Time

| CRS Dose | Time | | | | | |
|---|---|---|---|---|---|---|
| | Pre | | | Post | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 8.15 | 1.30 | 48 | 8.58 | 1.31 |
| B_level | 48 | 8.00 | 1.40 | 48 | 8.44 | 1.49 |
| C_level | 48 | 7.92 | 0.96 | 48 | 8.25 | 1.30 |

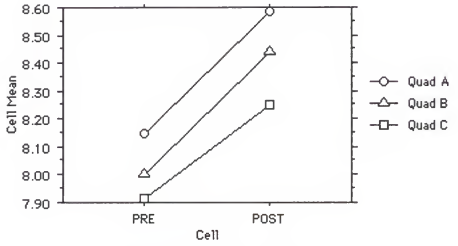



Figure 5-1. Means on Learner Response by CRS Dose for Force and Motion Problem Sets: Written.

Table 5-6
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose: Combined Problem Set x Time

| CRS Dose | Time | | | | | |
|---|---|---|---|---|---|---|
| | Pre | | | Post | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 6.16 | 1.11 | 48 | 5.95 | 1.28 |
| B_level | 48 | 5.87 | 0.97 | 48 | 5.93 | 1.11 |
| C_level | 48 | 5.57 | 0.98 | 48 | 5.82 | 0.87 |

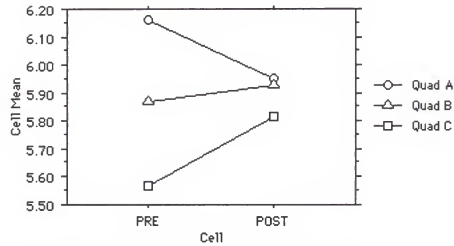



Figure 5-2. Means on Learner Response by CRS Dose for Force and Motion Problem Sets: Combined.

Table 5-7
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose: Less Difficult Problem Set x Time

| CRS Dose | Time | | | | | |
|---|---|---|---|---|---|---|
| | | Pre | | | Post | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 6.98 | 1.26 | 48 | 7.03 | 1.28 |
| B_level | 48 | 6.85 | 1.21 | 48 | 7.36 | 1.27 |
| C_level | 48 | 6.75 | 1.31 | 48 | 7.32 | 1.24 |

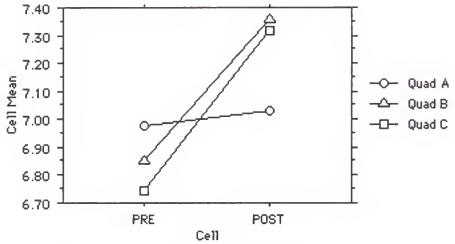



Figure 5-3. Means on Learner Response by CRS Dose for Force and Motion Problem Sets. Less Difficult.

Table 5-8
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose: More Difficult Problem Set x Time

| CRS Dose | Time | | | | | |
|---|---|---|---|---|---|---|
| | | Pre | | | Post | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 5.34 | 1.80 | 48 | 4.87 | 1.92 |
| B_level | 48 | 4.88 | 1.35 | 48 | 4.49 | 1.53 |
| C_level | 48 | 4.38 | 1.57 | 48 | 4.31 | 1.59 |

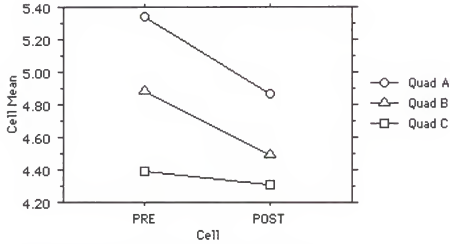



Figure 5-4. Means on Learner Response by CRS Dose for Force and Motion Problem Sets. More Difficult

Does a context effect depend on CRS Dose Level?

**Hypothesis 2: CRS level**

Ho: Changing CRS Dose level of experiential learning activities on force and motion systems from low to high resulted in no significant difference (invoked neither a less nor a more expert-like response) in learner outcomes in their abilities to solve force and motion problems on momentum after

participating in learning activities on force and motion concepts about momentum at a fixed CRS Dose level (A, B, or C).

The computed F value for learner success on combined less and more difficult force and motion problem sets was 16.35 at df=1. An interaction of problem set with CRS dose produced an F value of 3.52 at df=2 (Table 5-9). The computed F value for learner success on less difficult problem sets was 89.30 at df=1 (Table 5-10) and on more difficult problem sets was 4.70 at df=1 (Table 5-11). An interaction of more difficult problem set with CRS dose produced an F value of 5.79 at df=2 (Table 5-11). The F ratios 16.35, 3.52, 89.30, 4.70, 5.79 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for the study population. The means and standard deviations for Problem set by CRS dose are presented in Tables 5-12, 5-13, 5-14. Problem set and CRS dose interactions are plotted in Figures 5-5, 5-6, 5-7.

Learner overall success on problems about force and motion systems seemed to indicate a significant difference between learner success at higher levels of CRS dose than for lower to moderate levels of CRS dose on one (RM2) of the two problem sets of less and more difficult problems. Learner success on the less difficult problem sets seemed to be disordinal with CRS dose levels for one set (RM2_LD) but not the other. Learner success on the first problem set of less difficult problems (RM1_LD) was significantly greater than on the second set. Learner success on the more difficult problem sets appeared to be disordinal with the first set (RM1_MD) and ordinal with the second set (RM2_MD) of problems. Learners seemed to have significantly more success on the second problem set at higher CRS dose levels than they did on the first set of more difficult problems. Learners appeared to experience more success, on the second set of more difficult problems, at moderate to high levels of CRS dose than at low levels of CRS dose. And the opposite seemed to be true for the first set of more difficult problems.

Table 5-9
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: Less and More Difficult Combined Problem Sets.

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 3.58 | 2 | 1.79 | 0.86 | 0.19 |
| Subject(Group) | 294.52 | 141 | 2.09 | | |
| Problem Set | 19.32 | 1 | 19.32 | 16.35 * | 0.99 |
| Set X CRS Dose | 8.32 | 2 | 4.16 | 3.52 * | 0.64 |
| Set X Subject(Group) | 166.65 | 141 | 1.18 | | |

* Significant at p<.05

Table 5-10
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: Less Difficult Problem Sets

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 7.90 | 2 | 3.95 | 1.74 | 0.35 |
| Subject(Group) | 320.08 | 141 | 2.27 | | |
| Problem Set | 151.73 | 1 | 151.73 | 89.30 * | 1.00 |
| Set X CRS Dose | 7.17 | 2 | 3.59 | 2.11 | 0.41 |
| Set X Subject(Group) | 239.56 | 141 | 1.70 | | |

* Significant at p<.05

Table 5-11
Source Table of Analysis of Variance of CRS Dose
for Force and Motion Problems: More Difficult Problem Sets

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 0.96 | 2 | 0.48 | 0.13 | 0.07 |
| Subject(Group) | 522.54 | 141 | 3.71 | | |
| Problem Set | 9.00 | 1 | 9.00 | 4.70 * | 0.57 |
| Set X CRS Dose | 22.19 | 2 | 11.10 | 5.79 * | 0.88 |
| Set X Subject(Group) | 269.99 | 141 | 1.92 | | |

* Significant at p<.05

Table 5-12
Means and Standard Deviations for Learner Response
to Force and Motion Problems by CRS Dose for Two Sets
of Less and More Difficult Problems.

| CRS Dose | Problem Set | | | | | |
|---|---|---|---|---|---|---|
| | Set 1 | | | Set 2 | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 5.95 | 1.28 | 48 | 5.16 | 1.43 |
| B_level | 48 | 5.93 | 1.11 | 48 | 5.20 | 1.44 |
| C_level | 48 | 5.82 | 0.87 | 48 | 5.78 | 1.45 |

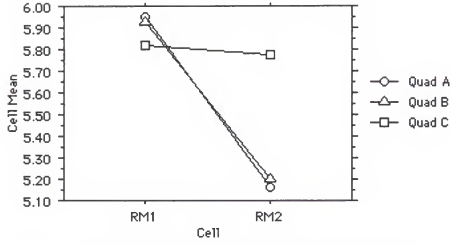



Figure 5-5. Means on Learner Response by CRS Dose for Two Force and Motion Problem Sets.
(RM1=Problem Set 1; RM2 = Problem Set 2)

Table 5-13
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose for Two Problem Sets. Less Difficult Problems

| CRS Dose | Problem Set | | | | | |
|---|---|---|---|---|---|---|
| | Set 1 | | | Set 2 | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 7.03 | 1.28 | 48 | 5.71 | 1.66 |
| B_level | 48 | 7.36 | 1.27 | 48 | 5.47 | 1.47 |
| C_level | 48 | 7.32 | 1.24 | 48 | 6.17 | 1.49 |

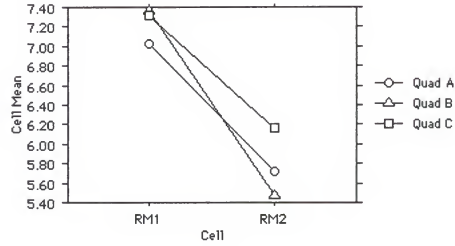



Figure 5-6. Means on Learner Response by CRS Dose for Two Force and Motion Problem Sets: Less Difficult (LD). (RM1=Problem Set 1; RM2 = Problem Set 2)

Table 5-14
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose for Two Problem Sets. More Difficult Problems

| CRS Dose | Problem Set | | | | | |
|---|---|---|---|---|---|---|
| | Set 1 | | | Set 2 | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 48 | 4.87 | 1.92 | 48 | 4.52 | 1.46 |
| B_level | 48 | 4.49 | 1.53 | 48 | 4.89 | 1.79 |
| C_level | 48 | 4.31 | 1.59 | 48 | 5.32 | 1.74 |

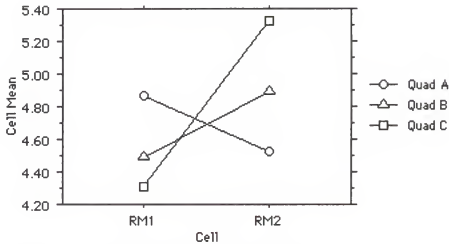



Figure 5-7. Means on Learner Response by CRS Dose for Two Force and Motion Problem Sets: More Difficult (MD). (RM1=Problem Set 1; RM2 = Problem Set 2)

The computed F value for novice learner success on force and motion problem sets having similar difficulty was 7.69 at df=1 (Table 5-15) and for intermediate learner success was 9.50 at df=1 (Table 5-16). An interaction of problem sets with CRS dose for intermediate learners produced an F value of 5.37 at df=2 (Table 5-16). The F ratios 7.69, 9.50, 5.37 are significant at $p < 0.05$. Hence, additional support that this null hypothesis was not accepted for the study population. The means and standard deviations for problem set by CRS dose are presented in Tables 5-17, 5-18. Problem set and CRS dose interactions are plotted in Figures 5-8, 5-9.

Novice learners at CRS dose level B performed poorer on the second problem set, while their counterparts at levels A and C indicated only a slight decrease in performance. However, intermediate learners at CRS dose level A indicated a decline in performance on the second problem set, while their counterparts at dose level B indicated less of a decline and those at level C indicated no change in performance. Intermediate learners seemed to have significantly more success on the second problem set at higher CRS dose levels than they did at lower levels and on the first set of problems. Novice learners seemed to have significantly more success on the second problem set at medium CRS dose levels than they did at either low or high levels and on the first set problems.

Table 5-15
Source Table of Analysis of Variance of CRS Dose
for Force and Motion Problems: Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 1.97 | 2 | 0.99 | 0.44 | 0.12 |
| Subject(Group) | 153.86 | 69 | 2.23 | | |
| Problem Set | 9.55 | 1 | 9.55 | 7.69 * | 0.79 |
| Set X CRS Dose | 7.29 | 2 | 3.64 | 2.93 | 0.55 |
| Set X Subject(Group) | 85.68 | 69 | 1.24 | | |

* Significant at $p<.05$

Table 5-16
Source Table of Analysis of Variance of CRS Dose for Force and Motion Problems: Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| CRS Dose | 5.66 | 2 | 2.83 | 1.43 | 0.29 |
| Subject(Group) | 136.15 | 69 | 1.97 | | |
| Problem Set | 9.77 | 1 | 9.77 | 9.50 * | 0.88 |
| Set X CRS Dose | 11.04 | 2 | 5.52 | 5.37 * | 0.84 |
| Set X Subject(Group) | 70.95 | 69 | 1.03 | | |

* Significant at p<.05

Table 5-17
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose for Two Problem Sets: Novice Learners

| CRS Dose | Problem Set | | | | | |
|---|---|---|---|---|---|---|
| | Set 1 | | | Set 2 | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 5.84 | 1.23 | 24 | 5.54 | 1.45 |
| B_level | 24 | 6.01 | 1.17 | 24 | 4.86 | 1.53 |
| C_level | 24 | 5.73 | 0.97 | 24 | 5.63 | 1.47 |

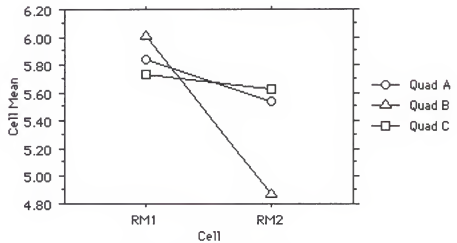



Figure 5-8. Means on Learner Response by CRS Dose for Two Force and Motion Problem Sets: Novice Learners. (RM1=Problem Set 1; RM2 = Problem Set 2)

Table 5-18
Means and Standard Deviations for Learner Response to Force and Motion Problems by CRS Dose for Two Problem Sets: Intermediate Learners

| CRS Dose | Problem Set | | | | | |
|---|---|---|---|---|---|---|
| | Set 1 | | | Set 2 | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 6.07 | 1.33 | 24 | 4.79 | 1.33 |
| B_level | 24 | 5.85 | 1.06 | 24 | 5.54 | 1.29 |
| C_level | 24 | 5.90 | 0.78 | 24 | 5.93 | 1.44 |

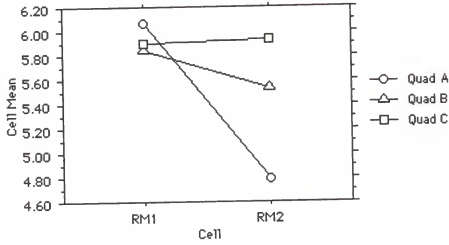



Figure 5-9. Means on Learner Response by CRS Dose for Two Force and Motion Problem Sets: Intermediate Learners. (RM1=Problem Set 1; RM2 = Problem Set 2)

Does context effect depend on the challenge level of force and motion problems (the problem level difficulty) present in CRS Dose learning activities and in assessment items on the force and motion cognitive instrument?

**Hypothesis 3: challenge Level**

Ho: Changing problem level difficulty from less to more difficult resulted in no significant difference on learner performance (invoke a less or more expert-like response) on momentum type force and motion problems where problem difficulty is associated with success and rigor of response to multi-

step versus single step force and motion problems. Learners of science and mathematics (poor and good) exhibited no significant difference in performance (experience no more gain or loss) on more difficult than on less difficult force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for problem difficulty was 99.26 at df=1 for novice learners and the F value was 133.85 at df=1 for intermediate learners (Tables 5-19, 5-20). The F ratios 99.26, 133.85 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted.

The means and standard deviations for learner response by problem difficulty and CRS dose are presented in Table 5-21 for novice learners and in Table 5-22 for intermediate learners. Learner response by problem difficulty and CRS dose interactions are plotted in Figure 5-10 for novice learners and in Figure 5-11 for intermediate learners. Both novice and intermediate learners seemed to be significantly more successful on less difficult problems about force and motion concepts than on problems having a higher level of challenge difficulty.

Table 5-19
Source Table of Analysis of Variance of Problem Difficulty and CRS Dose for Force and Motion Problem Sets for Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Problem Difficulty | 232.89 | 1 | 232.89 | 99.26 * | 1.00 |
| CRS Dose | 1.83 | 2 | 0.92 | 0.39 | 0.11 |
| Difficulty X Dose | 6.91 | 2 | 3.45 | 1.47 | 0.30 |
| Error | 323.81 | 138 | 2.35 | | |

* Significant at p<.05

Table 5-20
Source Table of Analysis of Variance of Problem Difficulty and CRS Dose for Force and Motion Problem Sets for Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Problem Difficulty | 284.68 | 1 | 284.68 | 133.85 * | 1.00 |
| CRS Dose | 1.28 | 2 | 0.64 | 0.30 | 0.10 |
| Difficulty X Dose | 7.15 | 2 | 3.57 | 1.68 | 0.34 |
| Error | 293.52 | 138 | 2.13 | | |

* Significant at p<.05

Table 5-21
Means and Standard Deviations for Learner Response to Force and Motion Problems by Problem Difficulty and CRS Dose for Novice Learners.

| CRS Dose | Problem Difficulty Level | | | | | |
|---|---|---|---|---|---|---|
| | Less Difficult | | | More Difficult | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 6.82 | 1.28 | 24 | 4.84 | 1.82 |
| B_level | 24 | 7.53 | 1.20 | 24 | 4.48 | 1.77 |
| C_level | 24 | 7.03 | 1.10 | 24 | 4.43 | 1.84 |

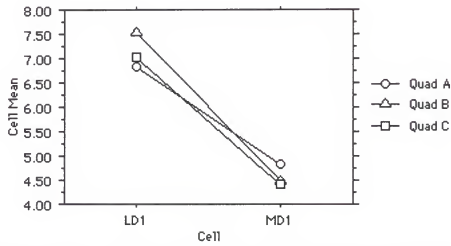



Figure 5-10. Means on Learner Response by Problem Difficulty and CRS Dose for Novice Learners. (LD1: less difficult; MD1: more difficult)

Table 5-22
Means and Standard Deviations for Learner Response to Force and Motion Problems by Problem Difficulty and CRS Dose for Intermediate Learners.

| CRS Dose | Problem Difficulty Level | | | | | |
|---|---|---|---|---|---|---|
| | Less Difficult | | | More Difficult | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 7.24 | 1.28 | 24 | 4.90 | 2.05 |
| B_level | 24 | 7.19 | 1.34 | 24 | 4.51 | 1.29 |
| C_level | 24 | 7.60 | 1.33 | 24 | 4.19 | 1.31 |

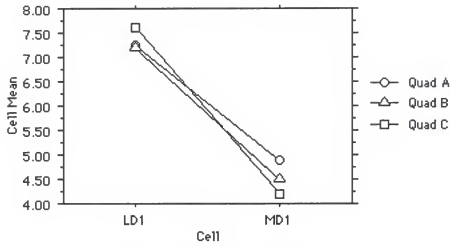



Figure 5-11. Means on Learner Response by Problem Difficulty and CRS Dose for Intermediate Learners. (LD1: less difficult; MD1: more difficult)

Do learners perform better on a question about momentum supported using interactive multimedia than on a traditional text-based question after immersion in visually enhanced interactive CRS type experiential learning activities on force and motion systems?

**Hypothesis 4: visual_IMM level**

Ho: Learners of science and mathematics exhibit no significant difference, are no more or less correct, in their response to an enhanced CRS type interactive multimedia-supported question on force and motion than to a traditional text-based question in the same context after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for instrument style was 19.35 at df=2 for novice learners and the F value was 21.82 at df=2 for intermediate learners. An instrument style by CRS dose interaction produced an F value of 0.62 at df=4 for novice learners and an F value of 2.70 at df=4 for intermediate learners (Tables 5-23, 5-24). The F ratios 19.3, 21.82, 2.70 are significant at $p < 0.05$. Therefore this null hypothesis was rejected. The means and standard deviations for learner response by instrument style and CRS dose are presented in Table 5-25 for novice learners and in Table 5-26 for intermediate learners. Learner response by instrument style and CRS dose interactions are plotted in Figure 5-12 for novice learners and in Figure 5-13 for intermediate learners.

Both novice and intermediate learners performed significantly better on instruments having a written text style and an interactive multimedia style than on an electronic text style instrument about force and motion concepts relative to rocket launching. While novice learners seemed to have a similar disordinal response across CRS dose level using either the written text or the multimedia instruments, the intermediate learners seemed to exhibit a disordinal response different from that of novice learners on the written text instrument while exhibiting an ordinal response on the multimedia instrument. The written text

instrument required learner free response to questions on the motion physics of rocket launching, and this added value of learner effort appears to result in better performance for both novice and intermediate learners. Likewise, the interactive multimedia instrument on the motion physics of rocket launching presented the learner with a considerable amount of dynamic context-based resources. This added value of context-based information pertaining to the motion physics of rocket launching seems to make force and motion concepts more intelligible for learners, novice and intermediate alike, as reflected in improved learner scores on the multimedia instrument relative to the electronic text instrument.

Table 5-23
Source Table of Analysis of Variance of Instrument Style and CRS Dose for Rocket Launch Force and Motion Problems: Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| Style | 24.33 | 2 | 12.17 | 19.35* | 1.00 |
| Style X CRS | 1.56 | 4 | 0.39 | 0.62 | 0.20 |
| Style X Subject(Group) | 86.78 | 138 | 0.63 | | |

* Significant at p<.05

Table 5-24
Source Table of Analysis of Variance of Instrument Style and CRS Dose for Rocket Launch Force and Motion Problems: Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| Style | 27.07 | 2 | 13.53 | 21.82* | 1.00 |
| Style X CRS | 6.69 | 4 | 1.67 | 2.70* | 0.74 |
| Style X Subject(Group) | 85.58 | 138 | 0.62 | | |

* Significant at p<.05

Table 5-25
Means and Standard Deviations for Learner Response to Rocket Launch Problems by Instrument Style and CRS Dose for Novice Learners.

| CRS Dose | Instrument Style | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Written_Text | | | Electronic_Text | | | Electronic_IMM | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 1.38 | 0.88 | 24 | 0.50 | 0.78 | 24 | 1.46 | 0.71 |
| B_level | 24 | 1.33 | 0.87 | 24 | 0.67 | 0.82 | 24 | 1.17 | 0.64 |
| C_level | 24 | 1.21 | 0.93 | 24 | 0.50 | 0.83 | 24 | 1.04 | 0.91 |

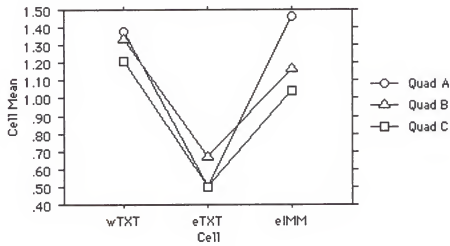



Figure 5-12. Means on Learner Response by Instrument Style and CRS Dose for Novice Learners. (wTXT: written text; eTXT: electronic text; eIMM: electronic interactive multi-media)

Table 5-26
Means and Standard Deviations for Learner Response to Rocket Launch Problems by Instrument Style and CRS Dose for Intermediate Learners.

| CRS Dose | Instrument Style | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Written_Text | | | Electronic_Text | | | Electronic_IMM | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 1.38 | 0.92 | 24 | 0.71 | 0.62 | 24 | 1.00 | 0.66 |
| B_level | 24 | 0.83 | 0.92 | 24 | 0.29 | 0.55 | 24 | 1.29 | 0.81 |
| C_level | 24 | 1.13 | 0.85 | 24 | 0.29 | 0.69 | 24 | 1.42 | 0.83 |

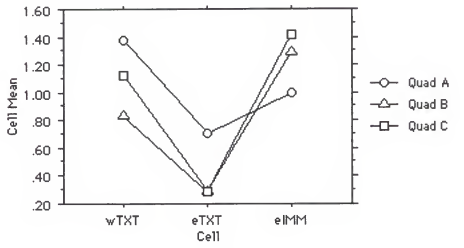



Figure 5-13. Means on Learner Response by Instrument Style and CRS Dose for Intermediate Learners. (wTXT: written text; eTXT: electronic text; eIMM: interactive multimedia)

Do learners perform better on a multimedia-based analytical question about momentum supported with a table or graph visual than on a text-based analytical question supported with a labeled picture visual after immersion in visually enhanced interactive CRS type experiential learning activities on force and motion systems?

**Hypothesis 5: visual_analytical level**

Ho: Learners of science and mathematics exhibit no significant difference, are no more or less correct, in their response to a more enhanced CRS type multimedia analysis type question illustrated using a table or graph visual than to a less enhanced text-based analysis type question illustrated using a labeled picture visual after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for visual tool was 0.28 at df=2 for novice learners and the F value was 1.05 at df=2 for intermediate learners. The computed F value for CRS dose effect was 0.34 at df=2 for novice learners and the F value was 4.24 at df=2 for intermediate learners (Tables 5-27, 5-28). Usage of a covariant, grade point average in science (GPA_S), produced an F value for GPA_S of 4.04 at df=1 for novice learners and an F value of 6.95 at df=1 for intermediate learners (Tables 5-27, 5-28). A visual tool by CRS dose interaction produced an F value of 1.59 at df=4 for novice learners and an F value of 2.55 at df=4 for intermediate learners (Tables 5-27, 5-28). A visual tool by CRS dose by GPA_S interaction produced an F value of 1.51 at df=4 for novice learners and an F value of 2.85 at df=4 for intermediate learners (Tables 5-27, 5-28). The F ratios 4.04, 4.24, 6.95, 2.55, 2.85 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners but accepted for novice learners. The means and standard deviations for visual tool by CRS dose are presented in Table 55-29 for novice learners and in Table 55-30 for intermediate learners. Visual tool and CRS dose

interactions are plotted in Figure 5-14 for novice learners and in Figure 5-15 for intermediate learners.

Most novice learners seemed to perform somewhat better using a dynamic graph when responding to analytical problems on force and motion, but some novice learners seemed to do better using a labeled picture. Most intermediate learners seemed to perform significantly better when using a labeled picture than when using either an illustrated data table or a dynamic graph as tools for analysis of force and motion problems. When using a labeled picture as a visual analysis tool, intermediate learners presented with low and high levels of CRS treatment performed about the same but significantly better than learners presented with a moderate level of CRS treatment. While intermediate learners seemed to do better than novice learners when using a labeled picture as a visual analytical tool, novice learners seemed to perform better when using a dynamic graph as a visual tool and performance seemed to decline for both groups when using an illustrated data table as a visual tool for analysis of force and motion type problems.

The added value of a dynamic interactive graph with flight clip as a visual tool seems to have made the analysis of force and motion problems more understandable for the younger novice learners but the dynamic graph did not appear to be as valuable for the older intermediate learners. The added value of a labeled picture with flight clip as a visual tool seems to have been more useful to intermediate learners than to novice learners. Both intermediate and novice learners seem to exhibit less preference for the usage of an illustrated data table with flight clip as a visual tool when analyzing force and motion problems. Force and motion problems for assessing learner usage of visual tools when analyzing force and motion problems used for testing this hypothesis are identified as labeled picture (PIC), illustrated table (TBL), and dynamically linked graph (GPH). The PIC type motion problem presented a labeled picture of aircraft takeoff with real-time clip of the takeoff event on a light pattern background; selection from an unnumbered list of

Table 5-27
Source Table of Analysis of Variance of Instrument Style and CRS Dose for Analytical Visual Tools Applied to Force and Motion Problems: Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Visual | 0.32 | 2 | 0.16 | 0.28 | 0.09 |
| CRS Dose | 0.40 | 2 | 0.20 | 0.34 | 0.10 |
| GPA_S | 2.34 | 1 | 2.35 | 4.04 * | 0.50 |
| Visual X CRS Dose | 3.70 | 4 | 0.93 | 1.59 | 0.48 |
| Visual X GPA_S | 0.24 | 2 | 0.12 | 0.21 | 0.08 |
| CRS Dose X GPA_S | 0.39 | 2 | 0.20 | 0.34 | 0.10 |
| Visual X CRS Dose X GPA_S | 3.51 | 4 | 0.88 | 1.51 | 0.45 |
| Error | 115.33 | 198 | 0.63 | | |

* Significant at p<.05

Table 5-28
Source Table of Analysis of Variance of Instrument Style and CRS Dose for Analytical Visual Tools Applied to Force and Motion Problems: Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Visual | 2.30 | 2 | 1.15 | 1.05 | 0.22 |
| CRS Dose | 9.32 | 2 | 4.66 | 4.24 * | 0.74 |
| GPA_S | 7.64 | 1 | 7.64 | 6.95 * | 0.76 |
| Visual X CRS Dose | 11.21 | 4 | 2.80 | 2.55 * | 0.71 |
| Visual X GPA_S | 3.05 | 2 | 1.52 | 1.39 | 0.28 |
| CRS Dose X GPA_S | 11.27 | 2 | 5.64 | 5.13 * | 0.83 |
| Visual X CRS Dose X GPA_S | 12.54 | 4 | 3.13 | 2.85 * | 0.77 |
| Error | 217.63 | 198 | 1.10 | | |

* Significant at p<.05

Table 5-29
Means and Standard Deviations for Learner Response to Aircraft Flight Analytical Problems by Visual Tool and CRS Dose for Novice Learners

| CRS Dose | Visual Tool | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Picture | | | Table | | | Graph | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 0.63 | 0.88 | 24 | 0.79 | 0.51 | 24 | 0.92 | 0.88 |
| B_level | 24 | 1.08 | 0.93 | 24 | 0.92 | 0.58 | 24 | 1.04 | 0.81 |
| C_level | 24 | 0.71 | 0.86 | 24 | 0.67 | 0.57 | 24 | 1.17 | 0.76 |

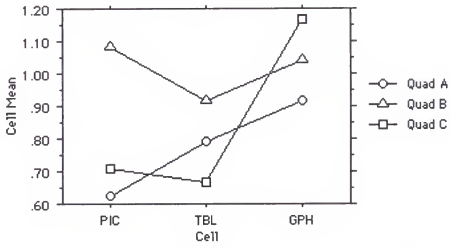



Figure 5-14. Means on Learner Response by Visual Tool and CRS Dose on Aircraft Flight Analytical Problems for Novice Learners. (PIC: picture; TBL: table; GPH: graph)

Table 5-30
Means and Standard Deviations for Learner Response to Aircraft Flight Analytical Problems by Visual Tool and CRS Dose for Intermediate Learners

| CRS Dose | Visual Tool | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Picture | | | Table | | | Graph | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 1.42 | 2.47 | 24 | 1.00 | 0.42 | 24 | 1.25 | 0.79 |
| B_level | 24 | 0.79 | 0.98 | 24 | 0.67 | 0.70 | 24 | 0.88 | 0.90 |
| C_level | 24 | 1.46 | 0.78 | 24 | 1.00 | 0.66 | 24 | 0.75 | 0.85 |

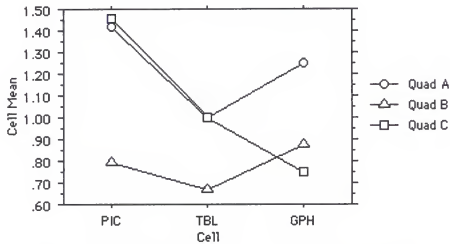



Figure 5-15. Means on Learner Response by Visual Tool and CRS Dose on Aircraft Flight Analytical Problems for Intermediate Learners. (PIC: picture; TBL: table; GPH: graph)

three items is made using a mouse click. The TBL type motion problem presented an illustrated data table for a moving aircraft with real-time clip of the event on an aircraft visual background; computations and results are keyboard entered using a text box. The GPH type motion problem presented a graph dynamically linked to a real-time clip of an aircraft in flight such that the graphical representation and the real-time visual of the aircraft movement are played back in a synchronized manner; computations and results are keyboard entered using a text box.

**Cluster B: Identifying with Diverse Learner Groups (IDLG)**

Does a context effect depend on number of formal years the learner studies science and mathematics?

**Hypothesis 6: learner level (NIE)**

Ho: Novice learners of science and mathematics exhibit no significant difference (are no less or more expert-like in their response) than intermediate learners in their ability to solve momentum type force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for novice and intermediate learners success on force and motion problems was 0.74 at df=1. An interaction of CRS Dose with Learner Level (FLS) produced an F value of 3.23 at df=2 for the study population aggregated as novice and intermediate learners (Table 5-31). The F ratio 3.23 is significant at $p < 0.05$. Therefore this null hypothesis was not accepted for the study population. The means and standard deviations for FLS by CRS dose are presented in Table 5-32; FLS and CRS dose interactions are plotted in Figure 5-16.

Learner success appears to be disordinal with CRS dose level for both novice and intermediate learners. Novice learners seemed to experience least success with the high CRS dose level and the greatest success with moderate CRS dose. Intermediate learners seem to have experienced the greatest success with low CRS dose level and the least success with moderate CRS dose. A significant interaction occurred between learner level and dose level in that novice learners presented with a moderate level of CRS dose activities appeared to be more successful than intermediate learners presented with this same CRS dose.

Scores from fifteen force and motion problems were aggregated and scaled into a single score for each learner representative of each group, novice and intermediate, in the study population. Problems ranged from less to more complex in level of difficulty and dealt with force and motion concepts related to momentum, impulse and force. Problems were presented through the computer in a contextually enhanced interactive multimedia format. The number of math courses taken by each learner was entered as a covariant in the ANOVA model.

Table 5-31
Source Table of Analysis of Variance of Learner Level (FLS) and CRS Dose for Force and Motion Problems

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| FLS | 13.59 | 1 | 13.59 | 0.74 | 0.13 |
| M_Crs | 25.80 | 1 | 25.80 | 1.41 | 0.21 |
| CRS Dose | 15.54 | 2 | 7.77 | 0.42 | 0.12 |
| FLS X M_Crs | 13.16 | 1 | 13.16 | 0.72 | 0.13 |
| FLS X CRS Dose | 118.16 | 2 | 59.08 | 3.23 * | 0.60 |
| M_Crs X CRS Dose | 42.43 | 2 | 21.22 | 1.16 | 0.24 |
| FLS X M_Crs X CRS Dose | 77.32 | 2 | 38.66 | 2.11 | 0.41 |
| Error | 2416.34 | 132 | 18.31 | | |

* Significant at p<.05

Table 5-32
Means and Standard Deviations for Learner Response to Force and Motion Problems by Learner Level (FLS) and CRS Dose

| CRS Dose | Learner Level: Novice | | | Intermediate | | |
|---|---|---|---|---|---|---|
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 10.58 | 4.45 | 24 | 10.58 | 4.82 |
| B_level | 24 | 11.63 | 4.57 | 24 | 8.25 | 4.19 |
| C_level | 24 | 9.21 | 3.85 | 24 | 9.46 | 4.06 |

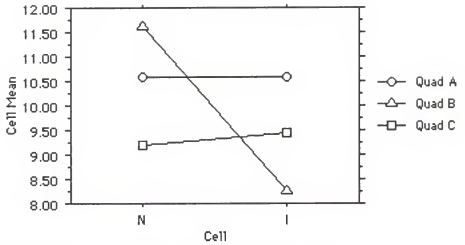



Figure 5-16. Means on Learner Response by Learner Level and CRS Dose on Force and Motion Problems. (N: Novice; I: Intermediate)

Does a context effect depend on the learner being a poor or good learner in science and mathematics?

**Hypothesis 7: learner type (PG)**

Ho: Poor learners in science and mathematics exhibit no significant difference (are no less or more expert-like in their response) compared to good learners in their ability to solve momentum type force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for the success of poor and good learners on a less difficult force and motion problem set was 6.15 at df=1 (Table 5-33). The computed F value for the success of poor and good learners on a more difficult force and motion problem set was 4.49 at df=1 (Table 5-34). The F ratio 6.15, 4.49 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for the study population. The means and standard

deviations for Learner Type (LT) by CRS dose are presented in Table 5-35, 5-36. LT and CRS dose interactions are plotted in Figures 5-17, 5-18.

Learner success appears to be disordinal with CRS dose level for good learners and ordinal for poor learners when responding to less difficult problems. Learner success appears to be disordinal with CRS dose level for both good and poor learners when responding to more difficult problems. When responding to less difficult problems, novice learners seemed to experience the greatest success with a high CRS dose level and intermediate learners seemed to have the greatest success with a moderate CRS dose; both experienced the least success with a low CRS dose. When responding to more difficult problems, both poor and good learners seemed to experience the greatest success with a low CRS dose level. Poor learners appeared to have about the same success on moderate to high CRS dose levels; while good learners appeared to have the least success at high CRS dose and about the same success at low to moderate CRS dose levels.

This hypothesis (Ho 7) focused on the connection between learner type, poor (P) and good (G) learners of science and mathematics, and learner success. Learner success was evaluated across problem challenge level, from less to more difficult problems, as a function of CRS dose level. Scores from four force and motion problems were aggregated and scaled into a single score for each learner of each group, good and poor, in the study population for both the less difficult and the more difficult problem sets. Problems ranged from less to more complex in level of difficulty and dealt with force and motion concepts related to momentum, impulse and force. Both less and more difficult problems were presented through the computer. Less difficult problems were presented in an electronic multiple-choice format and one was illustrated using a contextually enhanced interactive multimedia style. More difficult problems allowed for a free response through an electronic text box and all were contextually enhanced in a multimedia style. The context-rich, interactive multimedia (IMM) problems in themselves provided users an opportunity for a unique learning experience about related force and motion concepts.

Table 5-33
Source Table of Analysis of Variance of Learner Type (LT) and CRS Dose for Force and Motion Problems: Less Difficult Problem Set

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| LT | 9.45 | 1 | 9.45 | 6.15 * | 0.69 |
| CRS Dose | 3.03 | 2 | 1.52 | 0.98 | 0.21 |
| LT X CRS Dose | 2.32 | 2 | 1.16 | 0.75 | 0.17 |
| Error | 212.99 | 138 | 1.54 | | |

* Significant at p<.05

Table 5-34
Source Table of Analysis of Variance of Learner Type (LT) and CRS Dose for Force and Motion Problems: More Difficult Problem Set

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| LT | 12.56 | 1 | 12.56 | 4.49 * | 0.55 |
| CRS Dose | 7.82 | 2 | 3.91 | 1.40 | 0.29 |
| LT X CRS Dose | 1.90 | 2 | 0.95 | 0.34 | 0.10 |
| Error | 386.21 | 138 | 2.80 | | |

* Significant at p<.05

Table 5-35
Means and Standard Deviations for Learner Response to Force and Motion Problems by Learner Type (LT) and CRS Dose: Less Difficult Problem Set

| CRS Dose | Learner Level | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 6.82 | 1.22 | 24 | 7.24 | 1.33 |
| B_level | 24 | 6.93 | 1.33 | 24 | 7.79 | 1.07 |
| C_level | 24 | 7.19 | 1.06 | 24 | 7.45 | 1.40 |

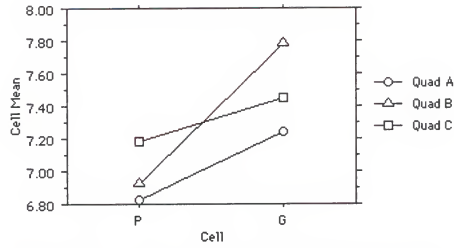



Figure 5-17. Means on Learner Response by Learner Type and CRS Dose for Force and Motion Problems: Less Difficult Problem Set. (P: Poor; G: Good)

Table 5-36
Means and Standard Deviations for Learner Response to Force and Motion Problems by Learner Type (LT) and CRS Dose: More Difficult Problem Set

| CRS Dose | Learner Level | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 24 | 4.64 | 2.16 | 24 | 5.10 | 1.65 |
| B_level | 24 | 4.04 | 1.50 | 24 | 4.95 | 1.45 |
| C_level | 24 | 4.12 | 1.54 | 24 | 4.51 | 1.64 |

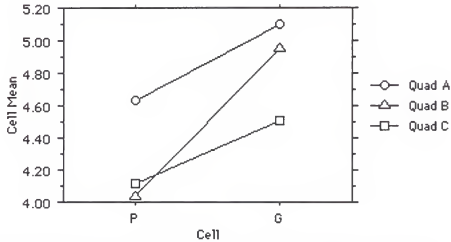



Figure 5-18. Means on Learner Response by Learner Type and CRS Dose for Force and Motion Problems: More Difficult Problem Set. (P: Poor; G: Good)

Does gender make a difference when evaluating learner response to momentum type force and motion questions after immersion in visually enhanced interactive CRS type experiential learning activities on force and motion systems?

**Hypothesis 8: gender (MF)**

Ho: Learners who are female show no significant difference, are no more or less correct, in their response to momentum type force and motion questions compared to learners who are male after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for male_female (MF) was 0.74 at df=1 for novice learners and the F value was 4.95 at df=1 for intermediate learners. The computed F value for CRS dose effect was 0.08 at df=2 for novice learners and the F value was 0.30 at df=2 for intermediate learners. Usage of a covariant, grade point average in Science (GPA_S), produced an F value for GPA_S of 2.02 at df=1 for novice learners and an F value of 8.32 at df=1 for intermediate learners. A MF by CRS dose interaction produced an F value of 1.56 at df=2 for novice learners and an F value of 0.36 at df=2 for intermediate learners. A MF by GPA_S interaction produced an F value of 0.50 at df=1 for novice learners and an F value of 3.89 at df=1 for intermediate learners (Tables 5-37, 5-38). The F ratios 4.95, 8.32, 3.89 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners but accepted for novice learners. The means and standard deviations for MF by CRS dose are presented in Table 5-39 for novice learners and in Table 5-40 for intermediate learners. MF and CRS dose interactions are plotted in Figure 5-19 for novice learners and in Figure 5-20 for intermediate learners.

Both male and female novice learners exhibit a disordinal response in degree of success on force and motion problems by CRS dose level and this disordinal pattern differs for males and females. However, the disordinal response by dose level is the same across

gender for intermediate learners. Although novice learners seem to achieve their greatest success on force and motion problems at a moderate CRS dose level with males performing better than females, intermediate learners experienced the least success at the same dose level with similar performance for both male and female learners. Success on force and motion problems seems to be significantly greater at both low and high CRS dose levels for intermediate male learners than for female learners.

Conceptual-based force and motion problems for the gender (male, female) comparison included six problems with a focus on momentum, impulse and force concepts (PIFs). Each PIF was presented on a cloud-sky horizon background blend and allowed for learner response by selection from an unnumbered list of five items using a mouse click.

Table 5-37
Source Table of Analysis of Variance of Gender and CRS Dose for Force and Motion Problems: Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| MF | 2.08 | 1 | 2.08 | 0.74 | 0.59 |
| CRS Dose | 0.47 | 2 | 0.24 | 0.08 | 0.10 |
| GPA_S | 5.69 | 1 | 5.69 | 2.02 | 0.83 |
| MF X CRS Dose | 8.78 | 2 | 4.39 | 1.56 | 0.10 |
| MF X GPA_S | 1.40 | 1 | 1.40 | 0.50 | 0.49 |
| MF X GPA_S | 1.02 | 2 | 0.51 | 0.18 | 0.17 |
| MF X CRS Dose X GPA_S | 6.75 | 2 | 3.38 | 1.20 | 0.09 |
| Error | 372.27 | 132 | 2.82 | | |

* Significant at $p<.05$

Table 5-38
Source Table of Analysis of Variance of Gender and CRS Dose for Force and Motion Problems: Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| MF | 19.56 | 1 | 19.56 | 4.95 * | 0.59 |
| CRS Dose | 2.35 | 2 | 1.18 | 0.30 | 0.10 |
| GPA_S | 32.90 | 1 | 32.90 | 8.32 * | 0.83 |
| MF X CRS Dose | 2.81 | 2 | 1.40 | 0.36 | 0.10 |
| MF X GPA_S | 15.36 | 1 | 15.36 | 3.89 * | 0.49 |
| MF X GPA_S | 5.84 | 2 | 2.92 | 0.74 | 0.17 |
| MF X CRS Dose X GPA_S | 1.92 | 2 | 0.96 | 0.24 | 0.09 |
| Error | 521.72 | 132 | 3.95 | | |

* Significant at p<.05

Table 5-39
Means and Standard Deviations for Learner Response to Force and Motion Problems by Gender and CRS Dose for Novice Learners

| CRS Dose | Gender | | | | | |
|---|---|---|---|---|---|---|
| | Female | | | Male | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 16 | 2.13 | 1.86 | 32 | 2.47 | 1.81 |
| B_level | 16 | 2.63 | 0.96 | 32 | 2.94 | 1.68 |
| C_level | 32 | 2.38 | 1.56 | 16 | 2.13 | 1.86 |

Table 5-40
Means and Standard Deviations for Learner Response to Force and Motion Problems by Gender and CRS Dose for Intermediate Learners

| CRS Dose | Gender | | | | | |
|---|---|---|---|---|---|---|
| | Female | | | Male | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 18 | 3.00 | 3.24 | 30 | 3.40 | 1.91 |
| B_level | 24 | 2.46 | 1.72 | 24 | 2.33 | 1.52 |
| C_level | 20 | 2.65 | 2.01 | 28 | 3.11 | 1.87 |

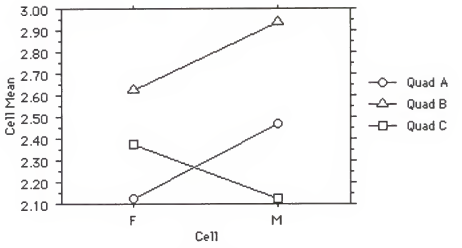



Figure 5-19. Means on Learner Response by Gender and CRS Dose on Force and Motion Problems for Novice Learners. (F: Female; M: Male)

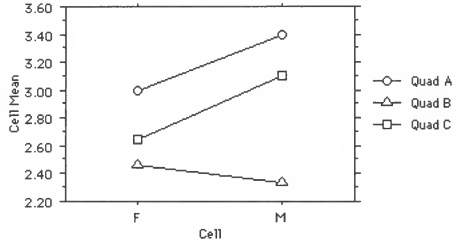



Figure 5-20. Means on Learner Response by Gender and CRS Dose on Force and Motion Problems for Intermediate Learners. (F: Female; M: Male)

Does race make a difference when evaluating learner response to momentum type force and motion questions after immersion in visually enhanced interactive CRS type experiential learning activities on force and motion systems?

**Hypothesis 9: race (BNB)**

Ho: Learners who are black show no significant difference, are no more or less correct, in their response to momentum type force and motion questions compared to learners who are non-black after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for intermediate black_non-black (BNB) learners was 4.22 at df=1 and 0.05 at df=1 for novice BNB learners. The computed F value for CRS dose effect was 0.34 at df=2 for novice learners and the F value was 3.19 at df=2 for intermediate learners. A BNB by CRS dose interaction produced an F value of 0.18 at df=2 for novice learners and an F value of 0.70 at df=2 for intermediate learners (Tables 5-41, 5-42). The F ratios 4.22, 3.19 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners but accepted for novice learners. The means and standard deviations for BNB by CRS dose are presented in Table 5-43 for novice learners and in Table 5-44 for intermediate learners. BNB and CRS dose interactions are plotted in Figure 5-21 for novice learners and in Figure 5-22 for intermediate learners.

Non-black learners seem to have a disordinal response in degree of success at both the novice and intermediate levels. Race identified as black and non-black does not appear to be a discriminator for novice learners presented with low CRS dose. Non-black intermediate learners presented with more CRS dose seem to perform significantly better than when presented with low CRS dose with learners having about the same success for both moderate and high CRS dose. And non-black intermediate learners presented with

moderate to high CRS dose seem to perform significantly better than black intermediate learners presented with low or moderate CRS dose of force and motion learning activities.

Conceptual-based force and motion problems for the race (black, non-black) comparison included six problems with a focus on momentum, impulse and force concepts (PIFs). Each PIF was presented on an enlarged image media background suggestive of a contextual setting in which the problem event occurs and allowed for learner response by selection from an array of items or objects using a mouse click. Problems were presented in a context-based media rich format with information pointers, directional arrows, supportive images, action clips, and access to hints through hypertext links.

Table 5-41
Source Table of Analysis of Variance of Race (BNB) and CRS Dose for Force and Motion Problems: Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| BNB | 0.15 | 1 | 0.94 | 0.05 | 0.06 |
| CRS Dose | 1.89 | 2 | 0.15 | 0.34 | 0.10 |
| BNB X CRS Dose | 0.98 | 2 | 0.49 | 0.18 | 0.08 |
| Error | 181.32 | 66 | 2.75 | | |

* Significant at p<.05

Table 5-42
Source Table of Analysis of Variance of Race (BNB) and CRS Dose for Force and Motion Problems: Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| BNB | 11.17 | 1 | 11.17 | 4.22* | 0.51 |
| CRS Dose | 16.90 | 2 | 8.45 | 3.19* | 0.58 |
| BNB X CRS Dose | 3.71 | 2 | 1.86 | 0.70 | 0.16 |
| Error | 174.94 | 66 | 2.65 | | |

* Significant at p<.05

Table 5-43
Means and Standard Deviations for Learner Response to Force and Motion Problems by Race (BNB) and CRS Dose for Novice Learners

| CRS Dose | Race | | | | | |
|---|---|---|---|---|---|---|
| | Black | | | Non-Black | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 4 | 4.90 | 0.71 | 20 | 4.90 | 1.69 |
| B_level | 4 | 4.58 | 1.48 | 20 | 4.42 | 1.84 |
| C_level | 6 | 4.72 | 1.51 | 18 | 5.23 | 1.60 |

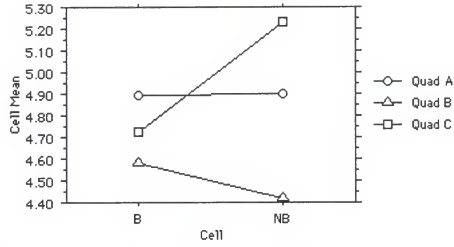



Figure 5-21. Means on Learner Response by Race and CRS Dose on Force and Motion Problems for Novice Learners. (B: Black; NB: Non-Black)

Table 5-44
Means and Standard Deviations for Learner Response to Force and Motion Problems by Race (BNB) and CRS Dose for Intermediate Learners

| CRS Dose | Race | | | | | |
|---|---|---|---|---|---|---|
| | Black | | | Non-Black | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 6 | 3.75 | 0.59 | 18 | 4.28 | 1.41 |
| B_level | 7 | 4.17 | 1.67 | 17 | 5.81 | 1.58 |
| C_level | 5 | 5.08 | 1.92 | 19 | 5.66 | 1.94 |

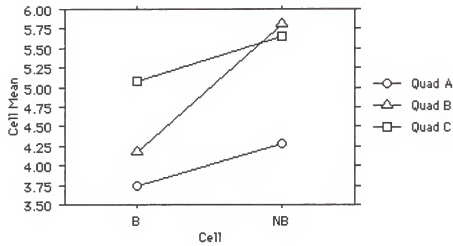



Figure 5-22. Means on Learner Response by Race and CRS Dose on Force and Motion Problems for Intermediate Learners. (B: Black; NB: Non-Black)

**Cluster C: Visual Tools for Improving Attitudes (VTIA-2)**

Does context effect depend on learner disposition towards tech tools?

**Hypothesis 10: tech attitude (TLT)**

Ho: Learners who have a more favorable disposition towards technology exhibit no significant difference (are no more or less expert-like) in their ability to solve momentum type force and motion problems than are learners who have a less favorable disposition towards technology after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for learner response to force and motion problems was 8.56 at df=2 and on usage of computer-based media in learning physics was 9.86 at df=1. The computed F value for learner response to force and motion problems was 8.10 at df=2 for novice learners and 2.39 at df=2 for intermediate learners. An interaction of learner performance with preference for technology based motion physics activities produced an F value of 4.40 at df=2 for novice learners and an F value of 1.74 for intermediate learners (Tables 5-45, 5-46, 5-47). The F ratios 8.56, 9.86, 8.10, 4.40 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted. The means and standard deviations for learner performance on pif problem sets (p, i, f) matched to learner preference (F, NF) for technology learning tools (Tech1 and Tech2) are presented in Tables 5-48, 5-49, 5-50. Learner performance by preference interactions is plotted in Figures 5-23, 5-24, 5-25.

Learners who did not favor usage of technology learning tools in the study of physics appeared to have more success in understanding momentum, impulse, and force concepts. But novice learners responding favorable towards the usage of technology learning tools seemed to have performed better on pif problem sets (sets p and i, but not f) than those making an unfavorable response. And intermediate learners responding non-favorably towards the usage of technology in motion physics seemed to have performed significantly better on pif problem sets (sets p and i, but not f) than those responding favorably. Also, novice learners appeared to be favorable towards technology learning tools more often than intermediate learners but learners, both novice and intermediate, favoring the usage of technology learning tools seemed to have less success in understanding physics concepts about force and motion systems than did those responding unfavorably towards technology. And as the motion physics became increasingly more difficult (from p to i to f), learners seemed to have about the same success on the physics problems whether or not they indicated a favorable response towards technology learning tools.

Table 5-45
Source Table of Analysis of Variance for Learner Performance on Force and Motion Problems Matched to Learner Preference for Technology Learning Tools

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| pif Set | 40.61 | 2 | 20.30 | 8.56 * | 0.98 |
| Tech1 Tools | 23.41 | 1 | 23.41 | 9.86 * | 0.90 |
| pif X Tools | 2.17 | 2 | 1.09 | 0.46 | 0.12 |
| Error | 1011.02 | 426 | 2.37 | | |

* Significant at p<.05

Table 5-46
Source Table of Analysis of Variance for Learner Performance on Force and Motion Problems Matched to Learner Preference for Technology Learning Tools: Novice

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| Tech2 Tools | 8.38 | 1 | 8.38 | 2.29 | 0.30 |
| Subject(Group) | 256.06 | 70 | 3.66 | | |
| pif Set | 21.31 | 2 | 10.65 | 8.10 * | 0.97 |
| pif X Tools | 11.59 | 2 | 5.79 | 4.40 * | 0.76 |
| pif X Subject(Group) | 184.13 | 140 | 1.32 | | |

* Significant at p<.05

Table 5-47
Source Table of Analysis of Variance for Learner Performance on Force and Motion Problems Matched to Learner Preference for Technology Learning Tools: Intermediate

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| Tech2 Tools | 7.56 | 1 | 7.56 | 2.14 | 0.29 |
| Subject(Group) | 247.55 | 70 | 3.54 | | |
| pif Set | 10.28 | 2 | 5.14 | 2.39 | 0.46 |
| pif X Tools | 7.50 | 2 | 3.75 | 1.74 | 0.35 |
| pif X Subject(Group) | 301.71 | 140 | 2.16 | | |

* Significant at p<.05

Table 5-48
Means and Standard Deviations for Learner Performance on pif Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech1)

| Tech1 Tool | pif Problem Sets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | p | | | i | | | f | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| F | 73 | 2.60 | 1.52 | 73 | 2.78 | 1.70 | 73 | 2.21 | 1.45 |
| NF | 71 | 3.03 | 1.48 | 71 | 3.44 | 1.41 | 71 | 2.52 | 1.66 |

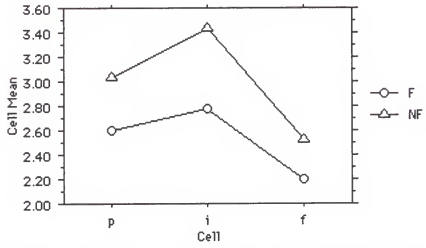



Figure 5-23. Means for Learner Performance on pif Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech1); (p: momentum; i: impulse; f: force; F: favorable response; NF: non-favorable response).

Table 5-49
Means and Standard Deviations for Learner Performance on pif Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech2): Novice

| Tech2 Tool | pif Problem Sets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | p | | | i | | | f | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| F | 52 | 2.87 | 1.42 | 52 | 3.54 | 1.49 | 52 | 2.12 | 1.53 |
| NF | 20 | 2.15 | 1.14 | 20 | 2.65 | 1.50 | 20 | 2.40 | 1.39 |

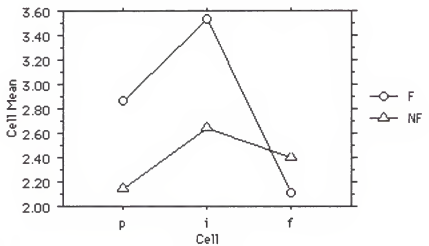



Figure 5-24. Means for Learner Performance on pif Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech2): Novice (p: momentum; i: impulse; f: force; F: favorable response; NF: non-favorable response).

Table 5-50
Means and Standard Deviations for Learner Performance on PIF Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech2): Intermediate

| Tech2 | pif Problem Sets | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tool | p | | | i | | | f | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| F | 42 | 2.60 | 1.64 | 42 | 2.79 | 1.80 | 42 | 2.55 | 1.66 |
| NF | 30 | 3.47 | 1.48 | 30 | 3.10 | 1.40 | 30 | 2.50 | 1.59 |

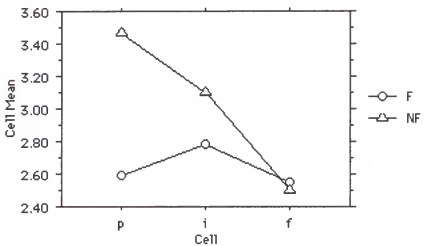



Figure 5-25. Means for Learner Performance on pif Problem Sets (p, i, f) Matched to Learner Preference (F, NF) for Technology Learning Tools (Tech2): Intermediate (p: momentum; i: impulse; f: force; F: favorable response; NF: non-favorable response).

Do learners of science and mathematics express confidence in their abilities to explain the momentum concept after immersion in visually enhanced interactive CRS type experiential learning activities on force and motion systems?

**Hypothesis 11: confidence level**

Ho: Learners of science and mathematics exhibit no significant difference, feel no less nor more confident, in their ability to explain momentum concepts to a friend after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F for learner confidence was 124.94 at df=2 for all learners, 5.10 at df=1 for learner type (good, poor), and 2.45 at df=2 for learner confidence by learner type (Table 5-51). The F ratios 124.94, 5.10, 2.45 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted. The means and standard deviations for the PSA cluster by learner confidence and learner type are presented in Table 5-52. The PSA cluster results by learner confidence and learner type are plotted in Figure 5-26.

More learners, good and poor, responded than did not respond regarding their confidence level about motion physics. And the learners responding positively tended to score significantly higher on the problem solving ability cluster than the learners responding non-positively. More poor than good learners expressed a positive confidence level. Slightly more good learners than poor learners decided not to risk a response. The same number of good learners responded as those that did not respond concerning their confidence level, however fewer good learners made a positive response than a non-response. Also, more poor learners responded than those that did not respond and the frequency of a positive response for poor learners was slightly less than their frequency of a non-response concerning their confidence level. However, it appears that good learners who felt less positive regarding their confidence level about motion physics tended to score significantly higher on the problem solving ability cluster than did the poor learners.

Table 5-51
Source Table of Analysis of Variance of Learner Confidence and Learner Type for PSA Cluster

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Learner Confidence | 423.41 | 2 | 211.70 | 124.94* | 1.00 |
| Learner Type | 8.64 | 1 | 8.64 | 5.10* | 0.60 |
| Confidence X Type | 8.30 | 2 | 4.15 | 2.45* | 0.47 |
| Error | 233.83 | 138 | 1.69 | | |

* Significant at p<.05

Table 5-52
Means and Standard Deviations for Learner Confidence and Learner Type on PSA Cluster

| Learner Type | Learner Confidence Response | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Response 1 | | | Response 0 | | | Response -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| Poor | 31 | 9.38 | 1.08 | 33 | 5.53 | 1.47 | 8 | 5.73 | 1.44 |
| Good | 27 | 9.29 | 1.13 | 36 | 5.90 | 1.44 | 9 | 7.22 | 1.10 |

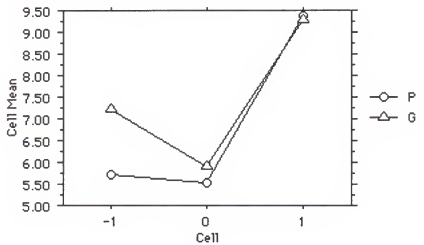



Figure 5-26. Means on PSA Cluster by Learner Confidence Response and Learner Type (Response 1: positive; Response –1: negative; Response 0: non-response; P = Poor; G = Good Learner Types).

Does context effect depend on the perceived locus of control reflecting learner level of expectation for success in science and mathematics using technology?

**Hypothesis 12: control and expectations (PLC, PSA, ALP)**

Ho: Learners who feel more in control of their learning (have a more positive perceived locus of control concerning their activities in science and mathematics using technology) exhibit no significant difference (are no more or less expert-like) in their ability to solve momentum type force and motion problems than do learners who feel less in control of their learning (have a less positive perceived locus of control) after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for learner perception in terms of learner response on a less difficult enhanced force and motion problem without FLS in the model was 0.65 at df=2 and on a more difficult enhanced problem was 4.15 at df=2. An interaction of CRS dose level with problem computed an F value of 2.75 at df=4 for the less difficult problem and an F value of 0.17 at df=4 for the more difficult problem (Tables 5-53, 5-54). The F ratios 4.15, 2.75 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted when considered in terms of contextually enhanced CRS type force and motion problems at low and high levels of difficulty. The means and standard deviations for Response Code by CRS Dose are presented in Tables 5-55, 5-56. Response code by CRS Dose interactions is plotted in Figures 5-27, 5-28.

The computed F value for learner perception in terms of learner response on a less difficult enhanced force and motion problem was 4.16 at df=2 and on a more difficult enhanced force and motion problem was 1.73 at df=2. The F value for learner perception in terms of CRS dose level was 4.96 at df=2 for the less difficult problem and was 1.52

for the more difficult problem. The F value for formal school level (FLS) was 0.003 at df=2 for the less difficult problem and was 6.32 for the more difficult problem. An interaction between problem set and CRS dose level computed an F value of 5.04 at df=2 for the less difficult problem and an F value of 2.21 at df=2 for the more difficult problem. The F ratios 4.16, 4.96, 6.32, 5.04 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted when considered in terms of contextually enhanced CRS type force and motion problems at low and high levels of difficulty.

Learner perception of ability and response performance on force and motion problems appeared to be influenced by CRS dose level more for less difficult force and motion problems than for more difficult problems. Learners responding to less difficult problems and making a correct response tended to have a more positive perception towards the study of science and mathematics than learners making a wrong response. However, learners electing to make a non-response seemed to have a more positive focus on science and mathematics that is higher than for learners responding correctly. Learners responding correctly to more difficult problems seemed to have a higher self-perception than if they respond incorrectly or withhold their response. Also, learners of force and motion concepts tended to have a disordinal perception-response with dose level.

Learners appeared not to respond more frequently on the more difficult problem than on the less difficult problem. They tended to make a correct response more often than a wrong response when answering the less difficult problem but seemed to make a wrong response about as frequently as a correct one when answering the more difficult problem.

There appeared to be a significant difference in the level of response (right, wrong, non-response) for the more difficult problem but not for the less difficult problem. A significant interaction between response level and CRS dose level seemed to be present for learners responding to the less difficult problem but did not appear to be significant in learner response for the more difficult problem. More importantly, learners responding

Table 5-53
Source Table of Analysis of Variance for Learner Perception Matched to CRS Dose and Learner Performance on Less Difficult Force and Motion Problems

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Shuttle Launch | 2.67 | 2 | 1.34 | 0.65 | 0.15 |
| LD Problems | 7.49 | 1 | 7.49 | 3.66 | 0.46 |
| CRS Dose | 8.94 | 2 | 4.47 | 2.19 | 0.43 |
| Launch X LD | 0.67 | 2 | 0.33 | 0.16 | 0.07 |
| Launch X Dose | 22.47 | 4 | 5.62 | 2.75 * | 0.74 |
| LD X Dose | 9.62 | 2 | 4.81 | 2.35 | 0.46 |
| Launch X LD X Dose | 20.82 | 4 | 5.20 | 2.54 * | 0.71 |
| Error | 257.73 | 126 | 2.05 | | |

* Significant at p<.05

Table 5-54
Source Table of Analysis of Variance for Learner Perception Matched to CRS Dose and Learner Performance on More Difficult Force and Motion Problems

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Jet Takeoff | 16.88 | 2 | 8.44 | 4.15 * | 0.73 |
| MD Problems | 0.01 | 1 | 0.01 | 0.01 | 0.05 |
| CRS Dose | 3.40 | 2 | 1.70 | 0.84 | 0.18 |
| Takeoff X MD | 17.71 | 2 | 8.85 | 4.35 * | 0.75 |
| Takeoff X Dose | 1.38 | 4 | 0.35 | 0.17 | 0.09 |
| MD X Dose | 8.55 | 2 | 4.28 | 2.10 | 0.41 |
| Takeoff X MD X Dose | 2.49 | 4 | 0.62 | 0.31 | 0.12 |
| Error | 256.34 | 126 | 2.03 | | |

* Significant at p<.05

Table 5-55
Means and Standard Deviations for Learner Perception Matched to Learner Response on Shuttle Launch Problem by CRS Dose and Less Difficult Problem Set

| Type Score | Shuttle Launch Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mea | SD | Count | Mean | SD |
| A Level | 19 | 6.88 | 1.51 | 21 | 7.31 | 1.47 | 8 | 7.27 | 1.70 |
| B Level | 19 | 6.60 | 1.34 | 21 | 5.99 | 1.91 | 8 | 6.46 | 1.00 |
| C Level | 19 | 7.02 | 1.22 | 9 | 7.52 | 1.28 | 14 | 6.47 | 1.36 |

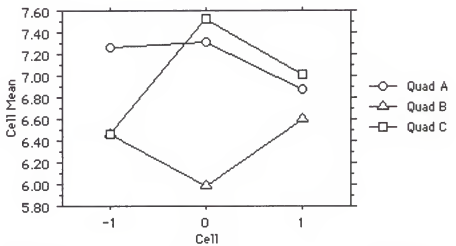



Figure 5-27. Means on Learner Perception by Response Code and CRS Dose (1: code right; -1 code wrong; 0 code no response; response code for shuttle launch problem).

Table 5-56
Means and Standard Deviations for Learner Perception Matched to Learner Response on Jet Takeoff Problem by CRS Dose and More Difficult Problem Set

| Type Score | Jet Takeoff Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| A Level | 7 | 8.30 | 1.01 | 27 | 7.17 | 1.50 | 14 | 6.47 | 1.40 |
| B Level | 15 | 6.76 | 1.03 | 22 | 6.09 | 1.80 | 11 | 6.13 | 1.70 |
| C Level | 18 | 7.26 | 1.13 | 15 | 6.95 | 1.59 | 15 | 6.58 | 1.14 |

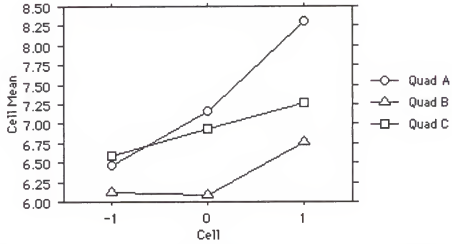



Figure 5-28. Means on Learner Perception by Response Code and CRS Dose (1: code right; -1 code wrong; 0 code no response; response code for jet takeoff problem).

the correct way to the more difficult problem seemed to have a more positive perception towards the study of science and mathematics than did learners responding correctly to the less difficult force and motion problem even though learners seemed to be successful more often (17%) on the less difficult than on the more difficult problems.

Assessment of learner perception towards science and mathematics was matched with learner performance on force and motion problems. The affective instrument PLC2 was used as a measure of learner perceived locus of control in science and mathematics using technology. The affective assessment instrument PLC2 included eight items that permitted sampling of learner viewpoints on science and mathematics in a technology

supported environment. Matched learner performance on less difficult and more difficult force and motion problem sets with the PLC2 measure was used to monitor learner perception against ability together with learner response trend on specific enhanced force and motion problems from their respective problem sets.

Two contextually enhanced force and motion problems were used to monitor learner conceptual response performance. The shuttle launch problem represented the contextually enhanced problem from the less difficult problem set and the jet takeoff problem represented the enhanced problem from the more difficult problem set. Learner response to the shuttle launch and jet takeoff problems was each coded as right (1), wrong (-1), or non-response (0). This nominal coding on learner response provided a way to monitor and match learner performance on conceptual force and motion problems with learner perception of science and mathematics.

> Does evaluation of learner response to the context effect depend on the presence of a non-ignorable non-response from homogeneous learner subgroups to assessment items on force and motion concepts involving momentum?

**Hypothesis 13: non-response gap (NRG)**

> Ho: Learner non-response items on an assessment instrument can be ignored as having no significant difference in the measure of the context effect on learner outcome when evaluating learner outcomes after having been involved in activities requiring complex mental problem solving processes using science and mathematics such as a fixed CRS dose level of experiential learning activities on force and motion systems.

The computed F value for Code (1, 0, -1) was 41.50 at df=2 for all learners, novice and intermediate. The computed F value for Type score (RWO, RW) was 198.96 at df=1 for all learners. A Type by Code interaction produced an F value of 80.79 at df=2 for all learners (Table 5-57). The computed F value for Type score (RWO) was 150.59 at

df=1 for all learners. A Level Studied (FLS) by Code interaction produced an F value of 3.91 at df=2 for all learners (Table 5-58). The computed F value for Type score (RW) was 45.64 at df=1 for all learners (Table 5-59). The F ratios 41.50, 198.96, 80.79, 150.59, 45.64, 3.91 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate and novice learners.

The means and standard deviations for Response Code by Type Score are presented in Tables 5-60, 5-61, 5-62, 5-63, 5-64. Response code by type score interactions are plotted in Figures 5-29, 5-30, 5-31, 5-32, 5-33. This analysis shows that the non-response code seems to significantly affect indicated learner outcome when learner non-response is scored as a wrong response rather than as a non-response in the assessment instrument. The non-response code seems to significantly affect the response pattern for both novice and intermediate learners monitored by their response to a specific problem contained within the assessment instrument.

Plots of mean responses for type score and response code for the specific problem (jet take off) seem to indicate a similar disordinal response pattern for both novice and intermediate learners. Mean scores for learners making a conviction seem to be somewhat higher for intermediate learners than for novice learners; and mean scores for learners having no conviction seem to be about the same for novice and intermediate learners. Mean scores on the instrument (RWO) scored in terms of the presence of a non-response indicate a wider spread than on the instrument (RW) scored ignoring the non-response of homogeneous learner groups as a separate code category. The instrument scored RW assigned learner non-response to the wrong response category in a way that total learner responses were conserved for computation of mean scores on the two assessment instruments.

As a result, the instrument scored RW presents averages for the non-response code separate from the wrong response code in the same manner as the same instrument scored RWO for the sake of evaluating the non-response effect on the overall assessment

instrument. Hence the wrong response mean values for the instrument scored RW would in fact be plotted somewhat higher than is apparent in the graphs but lower than the correct response mean values (Figures 5-29, 5-30, 5-31, 5-32, 5-33). The case presented for this analysis included about the same learner count for each learner group (novice, intermediate) in each response code category (RWO: right, wrong, non-response; and RW: right, wrong). Notice that although a majority of learners (about 56%) indicated a conviction (right or wrong) regarding the jet take off problem, a significant number of learners (about 44%) elected not to risk a response or otherwise failed to make a conviction regarding this problem. The instrument scored RW represents a common and traditional way of assessing student performance as a traditional binary response outcome (right, wrong) rather than allowing for additional categories such as is present in a more plausible trinomial response outcome (right, wrong, non-response) as indicated by the same instrument scored RWO.

Learner response on learning evaluation instrument items is either right or wrong and a third possibility of non-response seems to have importance, makes a significant difference, in evaluating learner ability in science and mathematics. Learner non-response items may at times comprise a sizeable portion of the total items on an evaluation instrument (about >10%) and prudence would suggest that non-response be taken into account when identifying learner outcomes due to treatment as after having received a fixed CRS dose level of experiential learning activities on force and motion systems. One must consider that the assignment of a large non-response group to the wrong response code category has certain potential for misguiding decision-making concerning curriculum programs and career directions (Appendix J). Perhaps a re-evaluation of the purposes and fairness in which assessment instruments are scored is in order. At the very least, research studies should be open to usage of additional response categories when assessing and evaluating results from diverse and different study populations of learners.

Table 5-57
Source Table of Analysis of Variance of Learner Response and Type Score for Force and Motion Problems for Novice and Intermediate Learners: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take Off Monitored

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Within Subjects | | | | | |
| Code (Jet Take Off) | 10.43 | 2 | 5.22 | 41.50 * | 0.99 |
| Subject(Group) | 0.38 | 3 | 0.13 | | |
| Type | 2.37 | 1 | 2.37 | 198.96 * | 1.00 |
| Type X Code | 1.93 | 2 | 0.96 | 80.79 * | 1.00 |
| Type X Subject(Group) | 0.04 | 3 | 0.01 | | |

* Significant at p<.05

Table 5-58
Source Table of Analysis of Variance of Learner Response for Force and Motion Problems by Learner Level (FLS: Novice and Intermediate Learners): More Difficult Problem Set (MD2) Scored as RWO; Response Code for Jet Take Off Monitored

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Code (Jet Take Off) | 275.27 | 2 | 137.63 | 150.59 * | 1.00 |
| FLS | 3.57 | 1 | 3.57 | 3.91 * | 0.49 |
| FLS X Code | 4.02 | 2 | 2.01 | 2.20 | 0.43 |
| Error | 126.13 | 138 | 0.91 | | |

* Significant at p<.05

Table 5-59
Source Table of Analysis of Variance of Response Code for Force and Motion Problems by Learner Level (FLS: Novice and Intermediate Learners): More Difficult Problem Set (MD2) Scored as RW: Response Code for Jet Take Off Monitored

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Code (Jet Take Off) | 45.07 | 2 | 22.54 | 45.64 * | 1.00 |
| FLS | 0.99 | 1 | 0.99 | 2.00 | 0.27 |
| FLS X Code | 1.51 | 2 | 0.76 | 1.53 | 0.31 |
| Error | 126.13 | 138 | 0.91 | | |

* Significant at p<.05

Table 5-60
Means and Standard Deviations for Learner Response to Force and Motion Problems by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW: Response Code for Jet Take Off Monitored; Means Scores for Novice and Intermediate Learners

| Type Score | Response Code 1 | | | 0 | | | -1 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| RWO | 2 | 6.58 | 0.27 | 2 | 3.42 | 0.07 | 2 | 5.64 | 0.49 |
| RW | 2 | 6.77 | 0.21 | 2 | 5.43 | 0.07 | 2 | 6.11 | 0.23 |

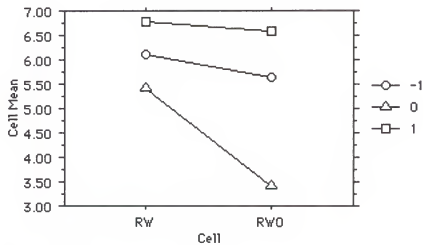



Figure 5-29. Means on Learner Response by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take Off Monitored; Means Scores for Novice and Intermediate Learners (RWO: right, wrong, no response; RW: right wrong; 1: code right; -1 code wrong; 0 code non-response).

Table 5-61
Means and Standard Deviations for Learner Response to Force and Motion Problems by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take Off Monitored; Means Scores for Novice Learners

| Type Score | Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| RWO | 20 | 6.40 | 0.96 | 31 | 3.47 | 0.88 | 21 | 5.30 | 1.35 |
| RW | 20 | 6.63 | 0.88 | 31 | 5.48 | 0.60 | 21 | 5.95 | 0.92 |

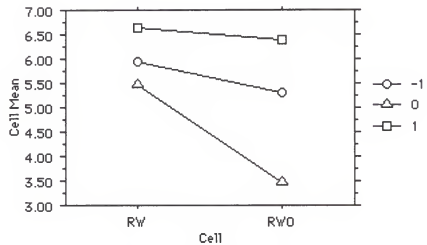



Figure 5-30. Means on Learner Response by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take-Off Monitored; Means Scores for Novice Learners (RWO: right, wrong, non-response; RW: right wrong; 1: code right; -1: code wrong; 0: code non-response).

Table 5-62
Means and Standard Deviations for Learner Response to Force and Motion Problems by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take Off Monitored; Means Scores for Intermediate Learners

| Type Score | Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| RWO | 20 | 6.77 | 0.49 | 33 | 3.37 | 0.76 | 19 | 5.99 | 1.19 |
| RW | 20 | 6.92 | 0.39 | 33 | 5.38 | 0.51 | 19 | 6.27 | 0.90 |

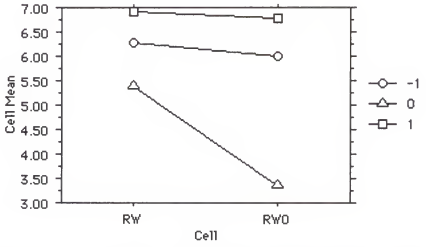



Figure 5-31. Means on Learner Response by Type Score and Response Code: More Difficult Problem Set (MD2) Scored as RWO and again as RW; Response Code for Jet Take-Off Monitored; Means Scores for Intermediate Learners (RWO: right, wrong, non-response; RW: right wrong; 1: code right; -1: code wrong; 0: code non-response).

Table 5-63
Means and Standard Deviations for Learner Response to Force and Motion Problems by Learner Level and Response Code: More Difficult Problem Set (MD2) Scored as RWO; Response Code for Jet Take Off Monitored

| Type | Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Score | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| N | 20 | 6.40 | 0.96 | 31 | 3.47 | 0.88 | 21 | 5.30 | 1.35 |
| I | 20 | 6.77 | 0.49 | 33 | 3.37 | 0.76 | 19 | 5.99 | 1.19 |

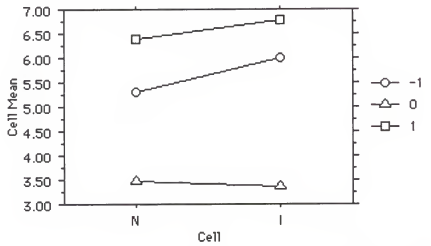



Figure 5-32. Means on Learner Response by Learner Level and Response Code: More Difficult Problem Set (MD2) Scored as RWO; Response Code For Jet Take-Off Monitored (RWO: right, wrong, non-response; N: novice, I: intermediate; 1: code right, -1: code wrong, 0: code non-response).

Table 5-64
Means and Standard Deviations for Learner Response to Force and Motion Problems by Learner Level and Response Code: More Difficult Problem Set (MD2) Scored as RW; Response Code for Jet Take Off Monitored

| Type | Response Code | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Score | 1 | | | 0 | | | -1 | | |
| | Count | Mean | SD | Count | Mean | SD | Count | Mean | SD |
| N | 20 | 6.63 | 0.88 | 31 | 5.48 | 0.60 | 21 | 5.95 | 0.92 |
| I | 20 | 6.92 | 0.39 | 33 | 5.38 | 0.51 | 19 | 6.27 | 0.90 |

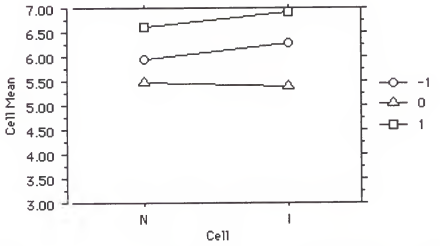



Figure 5-33. Means on Learner Response by Learner Level and Response Code: More Difficult Problem Set (MD2) Scored as RW; Response Code For Jet Take-Off Monitored (RW: right, wrong, non-response, (non-response = W); N: novice, I: intermediate; 1: code right, -1: code wrong, 0: code non-response).

**Cluster D: Nurturing a Progression of Learners towards Success (NPLS)**

Can a model be developed to study the cognitive and affective behavior of a study population of learners involved in specific experiential multimedia activities using multi-level contextual referent-image inquiry learning systems in a technology supported environment?

**Hypothesis 14: learning domains (CAD)**

A study of a population of learners will show no significant difference on cognitive and affective domain (CAD) measures of learner behavior due to having received CRS type experiential learning activities on force and motion systems about momentum.

The computed F value for affective domain (AD) in the cognitive domain model (CDM_AD_LT_CRS) with learner type (good, poor) and CRS dose level (A, B, C) in the model was 6.18 at df=1 for novice learners and the F value was 9.55 at df=1 for intermediate learners (Tables 5-65, 5-66). The computed F value for cognitive domain (CD) in the affective domain model (ADM_CD_LT_CRS) with learner type (good, poor) and CRS dose level (A, B, C) in the model was 7.84 at df=1 for novice learners and the F value was 9.15 at df=1 for intermediate learners (Tables 5-67, 5-68). The F ratios 6.18, 9.55, 7.84, 9.15 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners and novice learners from the point of view of both the cognitive and affective domains. The means and standard deviations for learner type by CRS dose are presented in Table 5-69 for novice learners and in Table 5-70 for intermediate learners. Learner type and CRS dose interactions are plotted in Figure 5-34, 5-36 for novice learners and in Figures 5-35, 5-37 for intermediate learners.

The computed F value for affective domain (AD) in the cognitive domain model (CDM_AD_FLS) with level studied (N,I,E) in the model was 20.33 at df=1 for good and poor learners; the F value for affective domain (AD) in the cognitive domain model (CDM_AD_LT) with learner type (G,P) in the model was 58.62 at df=1 for novice,

intermediate and expert learners; the F value for affective domain (AD) in the cognitive domain model (CDM_AD_CRS) with CRS dose level (A,B,C) in the model was 51.12 at df=1 for all learners. The F ratios 20.33, 58.62, 51.12 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners and novice learners from the point of view of both the cognitive and affective domains. The means and standard deviations for learner level by CRS dose are presented in Table 5-69 for novice learners and in Table 5-70 for intermediate learners. Learner level and CRS dose interactions are plotted in Figure 5-34 for novice learners and in Figure 5-35 for intermediate learners.

The computed F value for cognitive domain (CD) in the affective domain model (ADM_CD_FLS) with level studied (N,I,E) in the model was 20.98 at df=1 for good and poor learners; the F value for cognitive domain (CD) in the affective domain model (ADM_CD_LT) with learner type (G,P) in the model was 58.31 at df=1 for novice, intermediate and expert learners; the F value for cognitive domain (CD) in the affective domain model (ADM_CD_CRS) with CRS dose level (A,B,C) in the model was 62.09 at df=1 for all learners. The F ratios 20.98, 58.31, 62.09 are significant at $p < 0.05$. Therefore this null hypothesis was not accepted for intermediate learners and novice learners from the point of view of both the cognitive and affective domains. The means and standard deviations for learner level by CRS dose are presented in Table 5-71 for novice learners and in Table 5-72 for intermediate learners. Learner level and CRS dose interactions are plotted in Figure 5-36 for novice learners and in Figure 5-37 for intermediate learners.

Both poor and good novice learners exhibited a disordinal response by CRS dose level in success outcome on cognitive force and motion measures. Intermediate learners likewise seem to exhibit a disordinal success response, with good learners having greater success from moderate to high CRS dose levels and poor learners having lesser success from low to moderate CRS dose levels. Novice learners seemed to achieve their greatest

Table 5-65
Source Table of Analysis of Variance of Learner Affective Domain, Learner Type and CRS Dose for Learner Cognitive Domain of Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Affective Domain | 22.55 | 1 | 22.55 | 6.18 * | 0.70 |
| Learner Type | 2.67 | 1 | 2.67 | 0.73 | 0.13 |
| CRS Dose | 2.03 | 2 | 1.01 | 0.28 | 0.09 |
| AD X LT | 1.15 | 1 | 1.15 | 0.31 | 0.08 |
| AD X CRS Dose | 1.85 | 2 | 0.93 | 0.25 | 0.09 |
| LT X CRS Dose | 4.63 | 2 | 2.31 | 0.63 | 0.15 |
| AD X LT X Dose | 6.79 | 2 | 3.39 | 0.93 | 0.20 |
| Error | 744.80 | 204 | 3.65 | | |

* Significant at p<.05

Table 5-66
Source Table of Analysis of Variance of Learner Affective Domain, Learner Type and CRS Dose for Learner Cognitive Domain of Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Affective Domain | 30.15 | 1 | 30.15 | 9.55 * | 0.89 |
| Learner Type | 0.05 | 1 | 0.05 | 0.02 | 0.05 |
| CRS Dose | 9.13 | 2 | 4.57 | 1.45 | 0.30 |
| AD X LT | 2.11 | 1 | 2.11 | 0.67 | 0.12 |
| AD X CRS Dose | 14.62 | 2 | 7.31 | 2.32 | 0.45 |
| LT X CRS Dose | 0.35 | 2 | 0.17 | 0.06 | 0.06 |
| AD X LT X Dose | 0.15 | 2 | 0.07 | 0.02 | 0.05 |
| Error | 643.75 | 204 | 3.16 | | |

* Significant at p<.05

Table 5-67
Source Table of Analysis of Variance of Learner Cognitive Domain, Learner Type and CRS Dose for Learner Affective Domain of Novice Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Cognitive Domain | 25.45 | 1 | 25.45 | 7.84 * | 0.81 |
| Learner Type | 8.45 | 1 | 8.45 | 2.61 | 0.35 |
| CRS Dose | 10.27 | 2 | 5.13 | 1.58 | 0.32 |
| CD X LT | 4.05 | 1 | 4.05 | 1.25 | 0.19 |
| CD X CRS Dose | 5.05 | 2 | 2.52 | 0.78 | 0.18 |
| LT X CRS Dose | 3.11 | 2 | 1.56 | 0.48 | 0.13 |
| CD X LT X Dose | 6.77 | 2 | 3.39 | 1.04 | 0.22 |
| Error | 662.27 | 204 | 3.25 | | |

* Significant at p<.05

Table 5-68
Source Table of Analysis of Variance of Learner Cognitive Domain, Learner Type and CRS Dose for Learner Affective Domain of Intermediate Learners

| Source | SS (Type III) | DF | MS | F | Power |
|---|---|---|---|---|---|
| Between Subjects | | | | | |
| Cognitive Domain | 25.53 | 1 | 25.53 | 9.15 * | 0.87 |
| Learner Type | 1.81 | 1 | 1.81 | 0.65 | 0.12 |
| CRS Dose | 30.46 | 2 | 15.23 | 5.46 * | 0.86 |
| CD X LT | 0.06 | 1 | 0.06 | 0.02 | 0.05 |
| CD X CRS Dose | 12.10 | 2 | 6.05 | 2.17 | 0.43 |
| LT X CRS Dose | 0.44 | 2 | 0.22 | 0.08 | 0.06 |
| CD X LT X Dose | 1.70 | 2 | 0.85 | 0.30 | 0.10 |
| Error | 569.25 | 204 | 2.79 | | |

* Significant at p<.05

Table 5-69
Means and Standard Deviations for Learner Response to Cognitive Measures by Learner Type and CRS Dose for Novice Learners

| CRS Dose | Learner Type | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 36 | 6.47 | 2.03 | 36 | 6.98 | 1.89 |
| B_level | 36 | 6.15 | 2.07 | 36 | 6.97 | 2.08 |
| C_level | 36 | 6.51 | 1.66 | 36 | 6.50 | 1.81 |

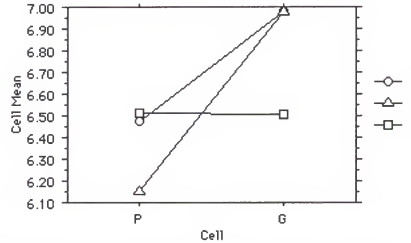



Figure 5-34. Means on Learner Response to Cognitive Measures by Learner Type and CRS Dose on Force and Motion Problems for Novice Learners. (P: Poor; G: Good)

Table 5-70
Means and Standard Deviations for Learner Response to Cognitive Measures by Learner Type and CRS Dose for Intermediate Learners

| CRS Dose | Learner Type | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 36 | 6.18 | 2.06 | 36 | 6.63 | 1.94 |
| B_level | 36 | 6.11 | 1.82 | 36 | 6.85 | 1.66 |
| C_level | 36 | 6.56 | 1.59 | 36 | 6.90 | 1.72 |

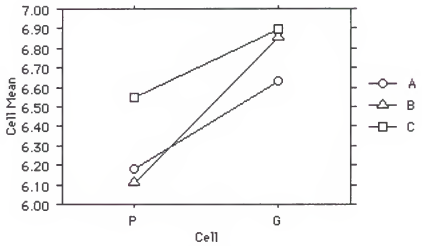



Figure 5-35. Means on Learner Response to Cognitive Measures by Learner Type and CRS Dose on Force and Motion Problems for Intermediate Learners. (P: Poor; G: Good)

Table 5-71
Means and Standard Deviations for Learner Response to Affective Measures by Learner Type and CRS Dose for Novice Learners

| CRS Dose | Learner Type | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 36 | 7.02 | 1.57 | 36 | 8.09 | 1.56 |
| B_level | 36 | 6.50 | 2.43 | 36 | 7.07 | 1.85 |
| C_level | 36 | 7.40 | 1.68 | 36 | 7.51 | 1.74 |

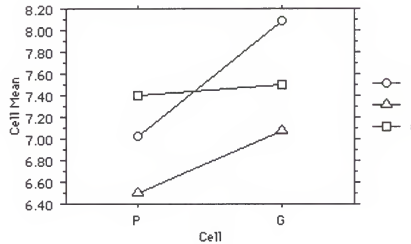



Figure 5-36. Means on Learner Response to Affective Measures by Learner Type and CRS Dose on Force and Motion Problems for Novice Learners. (P: Poor; G: Good)

Table 5-72
Means and Standard Deviations for Learner Response to Affective Measures by Learner Type and CRS Dose for Intermediate Learners

| CRS Dose | Learner Type | | | | | |
|---|---|---|---|---|---|---|
| | Poor | | | Good | | |
| | Count | Mean | SD | Count | Mean | SD |
| A_level | 36 | 7.23 | 2.00 | 36 | 7.48 | 1.83 |
| B_level | 36 | 6.31 | 1.86 | 36 | 5.63 | 1.47 |
| C_level | 36 | 7.34 | 1.67 | 36 | 6.31 | 1.24 |

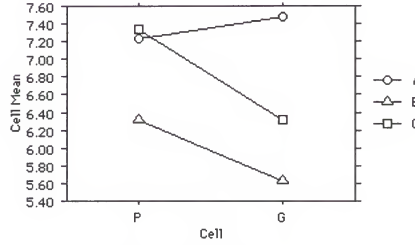



Figure 5-37. Means on Learner Response to Affective Measures by Learner Type and CRS Dose on Force and Motion Problems for Intermediate Learners. (P: Poor; G: Good)

success on cognitive measures at a low to moderate CRS dose level with good learners performing better than poor learners. Intermediate poor learners experienced the least success at low to moderate dose levels and intermediate good learners performed better than poor learners. Success for intermediate learners on cognitive measures of force and motion concepts seems to be significantly greater at all CRS dose levels for intermediate good learners than for poor learners.

Both poor and good novice learners exhibited a disordinal response by CRS dose level on affective measures of learner expectations towards science and mathematics; however, novice good learners did seem to make a favorable response more often than novice poor learners. Intermediate learners likewise seemed to exhibit a disordinal response pattern across CRS dose levels with good learners making a favorable response less often than poor intermediate learners. Novice learners seem to respond favorably on affective measures at low to moderate CRS dose levels, with good learners making a favorable response more often than poor learners. Also, intermediate poor learners seemed to respond favorably more often than intermediate good learners on learner expectations towards science and mathematics.

Conceptual force and motion problems (pifs) presented to the study population were grouped into three main categories (written (5), electronic_1 (8), electronic_2 (13)); the average response for each homogeneous learner group determined for each of the problems in a given problem category; and this average response entered into the analysis of variance as a repeated measure of the appropriate homogeneous learner group assigned to one of three CRS dose treatment levels (A,B,C) on the cognitive domain. All scores were scaled to an index of 10. Cognitive domain scores are of course matched to affective domain scores for subjects in each of the homogeneous learner groupings.

Learner expectations in science and mathematics (spexs) collected on the study population were grouped into three main categories (SMT (3), PLC1 (6), PLC2 (8)); the average response for each homogeneous learner group determined for each of the queries in

a given expectation category; and this average response entered into the analysis of variance as a repeated measure of the appropriate homogeneous learner group assigned to one of three CRS dose treatment levels (A,B,C) on the affective domain. All scores were scaled to an index of 10. Affective domain scores are of course matched to cognitive domain scores for subjects in each of the homogeneous learner groupings.

The research design identified a total of twelve homogeneous learner groups with twelve subjects per group. Since each subject is treated as a repeated measure for a specific learner group, twelve repeated measures were recorded for each homogeneous learner group. Learners were aggregated according to being good or poor learners of science and mathematics, being at the novice or intermediate level of formal schooling, and being in one of three CRS dose treatment levels. Also an expert group was identified for the study and members of this group performed all activities in the same way and during the same time period that the study population underwent treatment.

> Can a model be developed to study growth patterns of cognitive attitudes and abilities defined by a progression of learners of science and mathematics from a study population engaged in inquiry type experiential multimedia learning activities using multi-level contextual referent-image systems in a technology supported environment?

**Hypothesis 15: CRS and GOM models**

> Ho: Hypotheses 1 through 14, as construct tools for the research design model, show no significant difference in measurement of learner outcomes for learners receiving a fixed CRS dose level of experiential learning activities on force and motion systems reported for each of these hypotheses.

Consider the outcomes of null hypotheses 1 through 14 as being represented by independent flips of a coin, having only two values 0 (accept) and 1 (not accept), in terms of some other plausible hypotheses and the independent random variables associated with

these null hypotheses as being normally distributed over the range of possible values for each associated density function identifying the frequency of variable values within its allowed finite but continuous range. What results is the opportunity to model the problem presented by the null hypotheses 15 as a binomial distribution function, or more simply, the expression for a binomial probability function. That expression can bestated mathematically as:

$$Pr(X>k) = (n: k)\ p\ (1\text{-}p)$$

Where the coefficient (n: k) with p = 0.5 (a coin flip) can be identified from a symmetrical representation of the Pascal triangle or more elegantly using the factorial expression stated for n possible events taken k at a time as:

$$(n: k) = \frac{n!}{k!\ x\ (n\text{-}k)!}$$

The choice for n should be obvious to the reader as being the previous number of null hypothesis tested for significance in the study; namely, n = 14. The value for k is somewhat more elusive but easily captured by applying the confidence interval for values of variable x about its mean at $p < 0.05$; i.e. $\pm$ 1.96 SD (SD = 1 standard deviation about the mean). The problem resolves itself by identifying the mean and variance (and hence the standard deviation) for the collection of n cases. Probability theory identifies the mean $\mu$ for n cases (total possible outcomes) by the product (n x p) for which p is the probability of success (significance) and (1-p) is the probability of failure (non-significance). Note that since p = 0.5 (a coin flip), p and (1-p) take on identical values; i.e. 0.5. The expression for the mean evaluates to 7; i.e. (14 x 0.5 = 7). The variance for a binomial system is given by $\partial$ = n x p x (1-p) and the square root of this expression is the standard deviation (SD). The expression for SD evaluates to 1.87; i.e. (0.5 x (14)^1/2) and the critical value for p = 0.05 is 3.67; i.e. (1.96 x SD). Considering the high end of the normalized bell-shaped distribution function, this represents a threshold value for x of 10.67; i.e. ($\mu$ + 1.96 SD). Hence, to be outside of the laws of chance and thereby claim significance for this null

hypothesis regarding the research study model, the probability test $Pr(X > k)$ needs to be evaluated for $k = 11$.

Restated, significance can be claimed provided eleven or more of the null hypotheses 1 through 14 have been shown to be significant and the value $Pr(X>k)$ evaluates to a value equal to or less than the criterion $p = 0.05$. The outcome of $Pr(X>k)$ for $k = 11$(identified for 1.96SD), $n = 14$ and $p = 0.5$ is 0.02, which is less than the set criterion of 0.05. Indeed, previous analysis has established significance for each of the null hypothesis 1 through 14 and significance is likewise declared for null hypothesis 15 at $df = 14$ for $p<0.05$. Hence the null hypothesis 15 is not accepted by the laws of probability for the binomial theorem and the research designer model is considered validated for the target study population of learners on which it has been tested.

## Summary

Future investigative research involving a more extensive population of learners would provide an opportunity to further assess learner behavior patterns (i.e., identify how similar or dissimilar replication of some larger community of learners might be from what has been expressed through the research design model by the more limited population of learners used in this research study). Continued research opportunities for applications of the research designer model would provide additional learner behavior measurements, an opportunity for monitoring to what extent other learner populations might deviate from the observed target population of learners used for this study as well as how the current target population might change over time with continued intervention procedures.

The research designer model has provided an opportunity to explore a collection of factors that might be considered pertinent to procedures for making learning stuff more understandable to a given learner population; thereby, finding ways to focus and raise the level of learner success and to better allow opportunities for learner growth in a technology supported environment. The study hypotheses tested can be summarized into four types of model building tools for growing analytical caring minds (ACM):

(a) visual tools for inspiring analysis (VTIA-1: Ho 1, 2, 3, 4 , 5);

(b) identifying with diverse learner groups (IDLG: Ho 6, 7, 8, 9);

(c) visual tools for improving attitudes (VTIA-2: Ho 10, 11, 12, 13); and,

(d) nurturing a progression of learners towards success (NPLS: Ho 14, 15).

Ideally, this research study has focused on modeling tools for identifying learner success and focusing learner progress towards a more expert-like response (MER), thereby providing more learners the opportunity for passage to higher levels of achievement.

Learner growth patterns can and should be modeled and monitored in interesting and creative ways that would favor pushing the cognitive profile behaviors of learners in a way that could promote and accelerate their passage to higher levels of cognitive learning. Models provide tools not only for monitoring a given learner endeavor or state of functioning but also for focusing and sharpening learner behaviors in ways that provide opportunities for them to seek success at higher challenge levels of cognitive thought. More importantly, this research study suggests a learner cognitive profile approach that seeks to identify tools for promoting the intellectual growth of a community of diverse learners in a way that is more likely to enhance and extend current boundaries of human intelligence.

What has been tested through this study is a series of both subtle and complex ways of looking at the tech effect on education; ways for discovering the kinds of impact a technology supported learning environment might have on learner growth and development and for guiding the content of curricula programs designed to interface learners with the new wave of rapid information delivery systems. The intent has been to develop designer research modeling tools that might allow others ways to better envision tech systems that work best for learner success; ways for improving educational experiences while being sensitive to possible effects of rapid change on learning communities.

A primary goal of this study was to gather, design, develop, implement, and test plausible for instances for enhancing learning activities on force and motion in ways that

make the underlying concepts more understandable and interesting to the learner. Furthermore, the addition of a more expert-like response (MER) into the study suggests ways to gauge and focus directions for program modification and improvement as well as learner success. Matching learner effort against an expert referent response (ERR) familiar to their own immediate learning environment suggests goal posts that might seem more attainable to the learner and is more indicative of what might be expected in terms of learner progress on having completed a given course of study. The ERR is a ceiling on which learners can set their sights; identifies a maximum expected learner outcome to which learners might more readily relate; and provides ceiling reference for maximum possible success to aid in program evaluation and effectiveness. An ERR-like function is highly desirable for monitoring and assessing change in rapidly changing environments that promote the infusion of technology into the curriculum.

Interfacing rapid change technologies into classroom landscapes requires educators to become more sensitive to the diversity of learner characteristics, their tendencies towards technology usage, and what that might mean in terms of overall learner success. Today, education desperately needs ways for understanding learner perspectives in order that each learner may be empowered to take more control and accountability for his or her own learning. Whether usage of technology today be mindful or mindless, its impact on learning communities today sets directions for learner opportunities tomorrow. Hence, guarded implementation of technology through on-going research into educational programs of today is needed least the desired empowerment of today's learner becomes enslaved by outside controlling forces shaping tomorrows societies.

# CHAPTER 6
# CONCLUSIONS, EXTENSIONS AND RECOMMENDATIONS

## Research Model Overview

This research study designed, applied and investigated the development of research designer modeling tools as strategic ways for monitoring and assessing activity-based learner performance in a technology supported environment. These tools provide ways for studying differences between and within homogeneous learner groups of varying types (good and poor), level (novice and intermediate), gender (male and female) and race (black and non-black) in their abilities to solve momentum type problems involving force and motion systems when the level of the contextual-image referent system identifying the problem and the analytical challenge level difficulty of the problem presented are varied. A series of context-rich, hands-on, interactive multi-media activities involved learners in an instructional unit on force and motion systems and presented the underlying concepts about momentum, impulse and force. The degree of the learner being in control of learning was monitored through learner expectation clusters concerning science, mathematics and technology. Included in the study was an expert-referent response provided by learners who already had formal instruction on the underlying concepts of force and motion systems (Appendices B, D, E, F, H, I, K, L).

An analysis of variance, standard or repeated measures factorial design in split-plot form, was used to investigate the treatment effects. There were 72 middle school subjects identified as novice learners, 72 high school subjects identified as intermediate learners, and 36 high school subjects identified as expert learners that participated in the study. The learners, both novice and intermediate, were also divided equally by grade point average scores into good and poor learner groups. The learners were randomly assigned to one of

three different experimental groups, each group being distinguished by the level of contextual-image referent systems presented in force and motion activities.

All experimental groups interacted with activities on force and motion systems involving five multiple sequential tasks for engaging learners: managing a self-contained laboratory on force and motion systems using force and motion sensors; exploring points of view using a manipulative 3-D virtual cube on selective star systems; testing selective dynamic gravitational systems of orbiting bodies and then building new ones; exploring simulations of force and motion systems by adjusting and monitoring parameters of various moving objects over a range of values; and being immersed in a tutorial about flight explaining the underlying forces that cause the flight experience. All force and motion activities had real world analogues presented through appropriate technology supported environments. (Appendix C, Figures C-6 and C-7)

Each of the force and motion activities were repeated at three discrete levels of context and each context level contained more definitive and diverse contextual information than the previous (Appendices D, E, G). The three levels of context were (a) presence of a lower amount of real-world contextual information; (b) presence of a moderate amount of real-world contextual information; (c) presence of a higher amount of real-world contextual information. All learner groups participated in all five multiple tasks on force and motion systems, but only at one level of context. Each of the force and motion activities contained information at three levels of conceptual difficulty (momentum, impulse, and force) from less to more difficult. The three levels of conceptual difficulty were (a) lower level scenarios having more of a momentum emphasis; (b) moderate level scenarios having more of a momentum and impulse emphasis; (c) higher level scenarios having more of an impulse and force emphasis.

Each force and motion activity was accompanied with activity guide sheets providing directed assistance reading text (DART) while attending to that activity. The activity sheets included prompts for the learner's written response to the intended exercise and served as

checkpoints that focused the learner's attention in attending to selective information while performing the activity (Appendix G). Three levels of context-based visual imagery were incorporated into each of the three concept difficulty levels. The contextual levels were differentiated by the degree of visual definition and clarity and the contextual diversity of visual imagery 'for instances' presented in the force and motion learning activities. Three levels of context-based visual imagery were (1) lower level of context with at least one pictorial 'for instance' and usage of less visual imagery with more text; (2) moderate level of context with two or more pictorial 'for instances' and usage of more visual imagery with less text; (3) high level of context with four or more pictorial 'for instances' and usage of mostly visual imagery with less text illustrating the problem. Each learner participated at only one level of context, the treatment, and hence context was the research control variable for this study.

Each learner was evaluated pre and post on an affective instrument (6 responses per learner); pre and post on a cognitive instrument (22 responses per learner); post only on an affective instrument (5 responses per learner); post only on a cognitive instrument (13 responses per learner) for a total of 46 responses per learner on all affective and cognitive pre-post and post only instruments.

The following are the research questions in a nutshell which correlate with the study hypothesis tested and tools in the toolbox for building REAL science tech-models to grow analytical caring minds.

1. Does context make a difference in learning new stuff (Ho 1)?
2. Does context dosage make a difference (Ho 2)?
3. Does context dosage affect poor learners differently than good learners (Ho 7)?
4. Does context dosage affect novice and intermediate learners differently (Ho 6)?
5. Does problem media style influence the context effect (Ho 4)?
6. Does problem challenge difficulty level affect learner response (Ho 3)?
7. Does the form of visual analytical tool influence the context effect (Ho 5)?

8. Does a context medium influence learner expectations for success (Ho 12)?
9. Is a tech effect present in learner performance or attitude (Ho 10)?
10. Does gender make a difference in performance level or attitude (Ho 8)?
11. Does race make a difference in performance level or attitude (Ho 9)?
12. Does learner responsiveness vary with learner ability level (Ho 13)?
13. Do learners feel more in control of their learning (Ho 11)?
14. Does learner attitude toward science affect performance levels (Ho 14)?
15. Are the REAL science tech-models substantiated and well-founded (Ho 15)?

This research study has formulated a multi-faceted model for better understanding learner success when building new knowledge structures and understanding of that knowledge when learners are presented with new information varying in level of visual definition and clarity and contextual diversity through an interactive technology supported environment. The focus of this learning model is learner success and learner progress towards an obtainable goal of a more expert-like response (Appendix B). The model was tested and learner outcomes assessed for fifteen hypotheses describing the learning model. These fifteen hypotheses become the tools in the toolbox for building REAL science tech-models for growing analytical caring minds (ACM). The fifteen hypotheses can be grouped into four clusters concerned with learner responses as influenced through:

(a) cluster A: visual tools for inspiring analysis (VTIA-1) by ACM;

(b) cluster B: identifying with diverse learner groups (IDLG) as sources of ACM;

(c) cluster C: visual tools for improving attitudes (VTIA-2) of ACM;

(d) cluster D: nurturing a progression of learners toward success (NPLS) as ACM.

The first cluster, cluster A, investigates a context effect (Ho 1, Ho 2), a context-based challenge effect (Ho 3), and a context-based analysis tool effect (Ho 4, Ho 5). The context effect is tested in terms of its presence or absence and in terms of three discrete dosage levels from less to more context-based visual referent-imagery (Appendix I, Figures I-1 and I-2; Appendix M, Figures M-2 and M-3). The challenge effect is tested in terms of

three levels of problem difficulty (momentum, impulse, force), from less to more difficult in force and motion systems (Appendix I, Figures I-6 and I-7; Appendix M, Figures M-5 and M-6). The analysis tool effect is tested by learner response to three types of analytical visuals (picture, table, graph) used to extract, organize and evaluate data (Appendix I, Figure I-10).

The second cluster, cluster B, identifies the response levels characteristic of varied homogeneous learner groups in terms of ability level and in terms of demographics. Learner ability level was identified by learner type (Ho 7) and formal level studied (Ho 6). Learner type divided on two levels (good, poor) was equated to achievement in science and mathematics using computed learner grade point average in science and mathematics. Formal level studied (novice, intermediate, expert) was equated to school maturity level using learner grade level. Learner demographics was identified by gender (male, female; Ho 8)) and race (black, non-black; Ho 9)) (Appendix I, Figures I-1 to I-5).

The third cluster, cluster C, identifies varied learner expectations in science and mathematics in terms of a tech-effect (Ho 10), a learner confidence level (Ho 11), a learner perceived locus of control (Ho 12), and a non-response effect (Ho 13). The tech-effect considered learner response to written versus electronic questions and to electronic text versus electronic visual questions. Learner confidence level was a self-evaluation on feelings towards making explanations of momentum to another. Perceived locus of control involved learner perceptions towards science and mathematics in three areas: (1) problem solving ability; (2) awareness of learning progress; (3) technology as learning tools. The non-response effect compared learner response outcomes and related population statistics using trinomial and binomial probability functions in terms of three (right, wrong, non-response) versus two (right, wrong) homogeneous response categories (Appendix I, Figures I-8 to I-14; Appendix J; Appendix M, Figures M-3 and M-4).

The fourth cluster, cluster D, leverages conceptual growth through context-based imagery against learner expectations, perceptions, and attitudes and then culminates the

study in terms of a progression of learners from poor to good and from novice to intermediate towards the goal of success, that of a more expert-like response, MER. Leveraging learner performance against learner expectations shapes learner cognitive growth in terms of more positive learner cognitive attitudes (Ho 14). Leveraging learner performance against a time series of learner ability shapes learner cognitive growth along the journey to MER (Ho 15) (Appendix M, Figure M-7). Monitoring the study population as a progression of learners positions the learner for mastery through self-challenge activities; places learner focus on positive expectations and higher achievement by matching response level to that of a more expert-like response; provides opportunity for learners to gauge their progress toward a desired goal using indices akin to learner batting averages in the content area.

The learning model can be further condensed to an imaginary capsule likened to a Galaxy of the Mind (GOM), depicting a state of learner performance through a dynamic interplay of variable aptitudes of learner success with learner attitudes and presentations of contextually leveraged information for knowledge acquisition. The Galaxy of the Mind model looks at learner performance in an orbital mechanical way with a three axes system positioned in the center of the galaxy globe (Appendix B, Figure B-4).

The three axes represent dimensions of the learner constructs that orient the learner towards success. A horizontal axis perpendicular to this text represents the degree of learner control in the learning process from more to less; a horizontal axis perpendicular to the first and in the plane of this text represents the degree of context-based imagery from real to virtual; the vertical axis to this defined plane represents the degree of learner success from less to more-expert like in response and hence conceptual understanding. A donut shaped region centered on the origin of this three-dimensional reference system represents the dark matter of learner performance, the degree of learner non-response. Three visual imagery levels identify anchor points, three real and three virtual mirrored points, defining

three discrete context-based treatment levels used as the control variable of this research study.

Protruding from the galaxy center through the cloud of dark matter is a cone free to move about its central pivot point and having a helix-like core which spirals in and out as a function of the learner's cognitive parameters referenced to an expert-like response. This active cone with its helical core identifies the learner's orientation toward content mastery tracing out retrograde-like pathways as the learner moves through various formative stages toward full concept comprehension. As the learner's convictions become more expert-like, the learning cone passes through various critical points of comprehension and gravitates toward an expert-like zone. Once inside the expert zone, varied contextual 'for instances' seed and crystallize the learner's thoughts resulting in an 'Aha' experience. The learner's mental insight of concept formation matures to completion followed by a micro-mind explosion that catapults the learner's thoughts into another galaxy of the mind for continued formation, development, and advancement of thought. This spiraling cyclic process continues throughout life as the learner extends and enhances thought patterns and builds relevant knowledge bases needed for passage to higher ground and ever evolving levels of higher human intelligence (Appendix N).

## Research Model Findings

The data for novice and intermediate learners were analyzed with an analysis of variance, standard or repeated measures factorial design, in terms of an individual query item or a grouped data set of items used for testing each hypothesis. Additionally, the data for novice and intermediate learners were explored for strength of relationship to a more expert-like response from an expert learner group using several statistical tools including logistic regression, chi square contingency tables, and bivariate regression analysis. Each of the hypotheses is restated in the operational null form.

Hypothesis 1 (Ho 1): Learners of science and mathematics, referenced to an expert response, exhibited no significant difference in their abilities to solve momentum

type force and motion problems after receiving a fixed CRS Dose level (A, B, or C) of experiential learning activities on concepts about momentum in force and motion systems.

The null hypothesis (Ho 1) was not accepted.

Hypothesis 2 (Ho 2): Changing CRS Dose level of experiential learning activities on force and motion systems from low to high resulted in no significant difference (invoked neither a less nor a more expert-like response) in learner outcomes in their abilities to solve force and motion problems on momentum after participating in learning activities on force and motion concepts about momentum at a fixed CRS Dose level (A, B, or C).

The null hypothesis (Ho 2) was not accepted.

Hypothesis 3 (Ho 3): Changing problem level difficulty from less to more difficult results in no significant difference on learner performance (invoke a less or more expert-like response) on momentum type force and motion problems where problem difficulty is associated with success and rigor of response to multi-step versus single step force and motion problems. Learners of science and mathematics (poor and good) exhibit no significant difference in performance (experience no more gain or loss) on more difficult than on less difficult force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 3) was not accepted.

Hypothesis 4 (Ho 4): Learners of science and mathematics exhibit no significant difference, are no more or less correct, in their response to an enhanced CRS type interactive multimedia-supported question on force and motion than to a traditional text-based question in the same context after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 4) was not accepted.

Hypothesis 5 (Ho 5): Learners of science and mathematics exhibit no significant difference, are no more or less correct, in their response to a more enhanced CRS type multimedia analysis type question illustrated using a table or graph visual than to a less enhanced text-based analysis type question illustrated using a labeled picture visual after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 5) was not accepted.

Hypothesis 6 (Ho 6): Novice learners of science and mathematics exhibit no significant difference (are no less or more expert-like in their response) than intermediate learners in their ability to solve momentum type force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 6) was not accepted.

Hypothesis 7 (Ho 7): Poor learners in science and mathematics exhibit no significant difference (are no less or more expert-like in their response) compared to good learners in their ability to solve momentum type force and motion problems after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 7) was not accepted.

Hypothesis 8 (Ho 8): Learners who are female show no significant difference, are no more or less correct, in their response to momentum type force and motion questions compared to learners who are male after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 8) was not accepted.

Hypothesis 9 (Ho 9): Learners who are black show no significant difference, are no more or less correct, in their response to momentum type force and motion

questions compared to learners who are non-black after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 9) was not accepted.

Hypothesis 10 (Ho 10): Learners who have a more favorable disposition towards technology exhibit no significant difference (are no more or less expert-like) in their ability to solve momentum type force and motion problems than are learners who have a less favorable disposition towards technology after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 10) was not accepted.

Hypothesis 11 (Ho 11): Learners of science and mathematics exhibit no significant difference, feel no less nor more confident, in their ability to explain momentum concepts to a friend after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 11) was not accepted.

Hypothesis 12 (Ho 12): Learners who feel more in control of their learning (have a more positive perceived locus of control concerning their activities in science and mathematics using technology) exhibit no significant difference (are no more or less expert-like) in their ability to solve momentum type force and motion problems than do learners who feel less in control of their learning (have a less positive perceived locus of control) after having received a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 12) was not accepted.

Hypothesis 13 (Ho 13): Learner non-response items on an assessment instrument can be ignored as having no significant difference in the measure of the context effect on learner outcome when evaluating learner outcomes after having been involved in activities requiring complex mental problem solving processes using

science and mathematics such as a fixed CRS dose level of experiential learning activities on force and motion systems.

The null hypothesis (Ho 13) was not accepted.

Hypothesis 14 (Ho 14): A study of a population of learners will show no significant difference on cognitive and affective measures of learner behavior due to having received CRS type experiential learning activities on force and motion systems about momentum.

The null hypothesis (Ho 14) was not accepted.

Hypothesis 15 (Ho 15): Hypotheses 1 through 14, as construct tools for the research design model, show no significant difference in measurement of learner outcomes for learners receiving a fixed CRS dose level of experiential learning activities on force and motion systems reported for each of these hypotheses.

The null hypothesis (Ho 15) was not accepted.

## Research Study Discussion

The research findings are grouped into four categories that identify REAL science tech-models for growing analytical caring minds (ACM):

(a) cluster A: visual tools for inspiring analysis (VTIA-1) by ACM;

(b) cluster B: identifying with diverse learner groups as sources (IDLG) of ACM;

(c) cluster C: visual tools for improving attitudes (VTIA-1) of ACM;

(d) cluster D: nurturing a progression of learners toward success (NPLS) as ACM.

REAL science tech-models leverage technology supported environments in ways that promote Reality-based, Experiential Activities for Learning worlds of science.

### Cluster A: Visual Tools for Inspiring Analysis by ACM

A-1 (Ho 1): There was a significant difference in learner performance on problem solving as a result of treatment that was determined for both written and electronic problem sets on force and motion systems. Learners (novice and intermediate) had mean scores of

8.58 on the post and 8.15 on the pre written instrument at the lower CRS dose level; the mean scores were 8.44 on the post and 8.00 on the pre written instrument at moderate CRS dose level; the mean scores were 8.25 on the post and 7.92 on the pre written instrument at the higher CRS dose level. The electronic problem set indicated mean scores of 5.95 on the post but 6.16 on the pre at the lower CRS dose level; 5.93 on the post and 5.87 on the pre at the moderate CRS dose level; and 5.82 on the post and 5.57 on the pre at the higher CRS dose level. This indicates that overall learner response tended to improve with treatment for both written and electronic type instruments except for one lower dose incident for the electronic instrument. Learner performance tends to be lower on the more unfamiliar electronic instrument than on the more traditional written instrument.

A-2 (Ho 2): There was a significant difference in performance on conceptual problems between learners participating at one of three different levels of contextual referent-image dosages on force and motion systems. Learners (novice and intermediate) had mean scores of 7.03 and 5.71 at lower CRS dose, 7.36 and 5.47 at moderate CRS dose, and 7.32 and 6.17 at higher CRS dose for two less difficult problem sets (LD1, LD2). Learners (novice and intermediate) had mean scores of 4.87 and 4.52 at lower CRS dose, 4.49 and 4.89 at moderate CRS dose, and 4.31 and 5.32 at higher CRS dose for two more difficult problem sets (MD1, MD2). This indicates that learner response varies with problem sets within the same difficulty level. Learner performance on less difficult problem sets suggests a greater difference across problem sets than is indicated for the more difficult problem sets. The less difficult problem sets contained less than half as many context-rich problems as the more difficult problem sets and the non-context-rich problems, contained only in the less difficult problem sets, were presented in the traditional multiple choice format. Also, more items were included in the second problem sets (both less and more difficult) than in the first problem sets and overall learner response seems to become more variable across level of dose with increasing number of items in the problem sets for both less and more difficult problems. This indicates that learner response is

sensitive to the format in which the problem is presented and the number of problems in a problem set being presented at any given time. This suggests that CRS dose level positively influences learner performance as performance tends to improve more for learners presented with a higher level of CRS dose activities than for those presented with a lower CRS dose level.

A-3 (Ho 3): There was a significant difference in learner performance on problems of varying conceptual difficulty between learners participating at one of three different levels of contextual referent-image dosages on force and motion systems. On the first problem sets (LD1 and MD1), novice learners had mean scores of 6.82, 7.53, and 7.03 for less difficult (LD1) problems and mean scores of 4.84, 4.48, 4.43 for more difficult (MD1) problems; and intermediate learners had mean scores of 7.24, 7.19, 7.60 for less difficult problems and mean scores of 4.90, 4.51, 4.19 for more difficult problems at each of three levels of CRS dose. This suggests that learner performance (novice and intermediate) tends to vary inversely with problem challenge level, decreasing from less to more difficult problem sets. Also, learner performance shows an inversion across CRS dose level from less to more difficult problem sets for both novice and intermediate learners. This suggests that learners presented with activities having more context-rich real world visual imagery may reflect differently on problems from more varying points of view and range of depth of understanding than those presented with activities having less context-rich imagery. This added reflectivity on the part of the learner can be expected to result in a more variable response pattern and may account for the observed drop in performance on the more difficult problem set by learners receiving the higher CRS dose level of treatment of force and motion activities.

A-4 (Ho 4): Both novice and intermediate learners performed significantly better on instruments having a written text style and an interactive multimedia style than on an electronic text style instrument about force and motion concepts relative to rocket launching. Novice learners responded to rocket launch problems presented as written text,

electronic text, and electronic interactive multimedia with mean scores of 1.38, 0.50, 1.46 at low CRS dose level, mean scores of 1.33, 0.67, 1.17 at moderate CRS dose level, and mean scores of 1.21, 0.50, 1.04 at high CRS dose level. Intermediate learners responded to rocket launch problems presented as written text, electronic text, and electronic interactive multimedia with mean scores of 1.38, 0.71, 1.00 at low CRS dose level, mean scores of 0.83, 0.29, 1.29 at moderate CRS dose level, and mean scores of 1.13, 0.29, 1.42 at high CRS dose level. While novice learners seemed to have a similar disordinal response across CRS dose level using either the written text or the multimedia instruments, the intermediate learners seemed to exhibit a disordinal response different from that of novice learners on the written text instrument while exhibiting an ordinal response on the multimedia instrument. The written text instrument required learner free response to questions on the motion physics of rocket launching, and this added value of learner effort appears to result in better performance for both novice and intermediate learners. Likewise, the interactive multimedia instrument on the motion physics of rocket launching presented the learner with a considerable amount of dynamic context-based resources. This added value of context-based information pertaining to the motion physics of rocket launching seems to have made these force and motion concepts more intelligible for learners, novice and intermediate alike, as reflected in improved learner scores on the multimedia instrument relative to the electronic text instrument.

A-5 (Ho 5): There was a significant difference in learner performance on problems presented using varying visual analytical tools between learners participating at one of three different levels of contextual referent-image dosages on force and motion systems. Novice learners responded to aircraft flight analytical problems presented using a labeled picture, data table, and dynamic graph with mean scores of 0.63, 0.79, 0.92 at low CRS dose level, mean scores of 1.08, 0.92, 1.04 at moderate CRS dose level, and mean scores of 0.71, 0.67, 1.17 at high CRS dose level. Intermediate learners responded to aircraft flight analytical problems presented using a labeled picture, data table, and dynamic graph with

mean scores of 1.42, 1.00, 1.25 at low CRS dose level, mean scores of 0.79, 0.67, 0.88 at moderate CRS dose level, and mean scores of 1.46, 1.00, 0.75 at high CRS dose level. Most novice learners seemed to perform somewhat better using a dynamic graph when responding to analytical problems on force and motion, but some novice learners seemed to do better using a labeled picture. Most intermediate learners seemed to perform significantly better when using a labeled picture than when using either an illustrated data table or a dynamic graph as tools for analysis of force and motion problems. When using a labeled picture as a visual analysis tool, intermediate learners presented with low and high levels of CRS treatment performed about the same but significantly better than learners presented with a moderate level of CRS treatment. While intermediate learners seemed to do better than novice learners when using a labeled picture as a visual analytical tool, novice learners seemed to perform better when using a dynamic graph as a visual tool and performance seemed to decline for both groups when using an illustrated data table as a visual tool for analysis of force and motion type problems. The added value of a dynamic interactive graph with flight clip as a visual tool seems to have made the analysis of force and motion problems more understandable for the younger novice learners but the dynamic graph did not appear to be as valuable for the older intermediate learners. The added value of a labeled picture with flight clip as a visual tool seems to have been more useful to intermediate learners than to novice learners. Both intermediate and novice learners seem to exhibit less preference for the usage of an illustrated data table with flight clip as a visual tool when analyzing force and motion problems.

**Cluster B: Identifying with Diverse Learner Groups as Sources of ACM**

B-1 (Ho 6): There was a significant difference in performance on force and motion problems between learners indicated by an interaction of formal level studied (novice, intermediate) with level of participation (lower, moderate, higher) in CRS dose experiential learning activities on force and motion systems. Novice learners responded to fifteen problems on force and motion concepts with mean scores of 10.58, 11.63, 9.21 at lower,

moderate, and higher CRS dose levels of force and motion activities. Intermediate learners responded to fifteen problems on force and motion concepts with mean scores of 10.58, 8.25, 9.46 at lower, moderate, and higher CRS dose levels of force and motion activities. Scores from fifteen force and motion problems were aggregated and scaled into a single score for each learner representative of each group, novice and intermediate, in the study population. Problems ranged from less to more complex in level of difficulty and dealt with force and motion concepts related to momentum, impulse and force. Problems were presented through the computer in an contextually enhanced interactive multimedia format. The number of math courses taken by each learner was entered as a covariant in the anova model. Learner success appears to be disordinal with CRS dose level for both novice and intermediate learners. Novice learners seem to experience least success with the high CRS dose level and the greatest success with moderate CRS dose. Intermediate learners seem to experience the greatest success with low CRS dose level and the least success with moderate CRS dose. A significant interaction occurred between learner level and dose level suggesting that novice learners presented with a moderate level of CRS dose activities have a tendency to be more successful than intermediate learners presented with this same CRS dose.

B-2 (Ho 7): There was a significant difference in performance on less and more difficult force and motion problems between learners indicated by learner type (poor, good) and level of participation (lower, moderate, higher) in CRS dose experiential learning activities on force and motion systems. Poor learners responded to four less difficult problems on force and motion concepts with mean scores of 6.82, 6.93, 7.19 at lower, moderate, and higher CRS dose levels of force and motion activities; and to four more difficult problems with mean scores of 4.64, 4.04, 4.12 at lower, moderate, and higher CRS dose levels of force and motion activities. Good learners responded to four less difficult problems on force and motion concepts with mean scores of 7.24, 7.79, 7.45 at lower, moderate, and higher CRS dose levels of force and motion activities; and to four

more difficult problems with mean scores of 5.10, 4.95, 4.51 at lower, moderate, and higher CRS dose levels of force and motion activities. Learner success appears to be disordinal with CRS dose level for good learners and ordinal for poor learners when responding to less difficult problems. Learner success appears to be disordinal with CRS dose level for both good and poor learners when responding to more difficult problems. When responding to less difficult problems, novice learners seem to experience the greatest success with a high CRS dose level and intermediate learners seem to have the greatest success with a moderate CRS dose; both learner types indicate a tendency to experience the least success with a low CRS dose. This suggest that when responding to more difficult problems, both poor and good learners show a tendency to experience the greatest success with a low CRS dose level. Poor learners appear to have about the same success on moderate to high CRS dose levels; while good learners appear to have the least success at high CRS dose and about the same success at low to moderate CRS dose levels. Scores from four force and motion problems were aggregated and scaled into a single score for each learner of each group, good and poor, in the study population for both the less difficult and the more difficult problem sets. Problems ranged from less to more complex in level of difficulty and dealt with force and motion concepts related to momentum, impulse and force. Both less and more difficult problems were presented through the computer. Less difficult problems were presented in an electronic multiple choice format and one was illustrated using a contextually enhanced interactive multimedia style. More difficult problems allowed for a free response through an electronic text box and all were contextually enhanced in a multimedia style.

B-3 (Ho 8): There was a significant difference in performance on less and more difficult force and motion problems between intermediate but not novice learners indicated by gender (female, male) and level of participation (lower, moderate, higher) in CRS dose experiential learning activities on force and motion systems. Female intermediate learners responded to six problems on momentum, impulse and force concepts with mean scores of

3.00, 2.46, 2.65 at lower, moderate, and higher CRS dose levels of force and motion activities. Male intermediate learners responded to six problems on momentum, impulse and force concepts with mean scores of 3.40, 2.33, 3.11 at lower, moderate, and higher CRS dose levels of force and motion activities. Scores for novice learners participating in lower, moderate, and higher CRS dose levels of force and motion activities were 2.13, 2.63, 2.38 for novice females and 2.47, 2.94, 2.13 for novice males. Conceptual-based force and motion problems for the gender (male, female) comparison included six problems with a focus on momentum, impulse and force concepts (PIFs). Each PIF was presented on a cloud-sky horizon background blend and allowed for learner response by selection from an unnumbered list of five items using a mouse click.

Both male and female novice learners seem to exhibit a disordinal response in degree of success on force and motion problems by CRS dose level and this disordinal pattern, although tested to be non-significant on gender, differs for males and females. And intermediate male and female learners likewise seem to exhibit a disordinal response by dose level but this response pattern, which tested to be significant on gender, appears to be the same across gender. Although novice learners seem to achieve their greatest success on force and motion problems at a moderate CRS dose level with males performing better than females, intermediate learners seem to experience the least success at the same moderate dose level with similar performance for both male and female learners. This suggests that success on force and motion problems seems to be significantly greater at both low and high CRS dose levels for intermediate male learners than for intermediate female learners.

B-4 (Ho 9): There was a significant difference in performance on six visual, interactive context-rich force and motion problems between intermediate but not novice learners indicated by race (black, non-black) and level of participation (lower, moderate, higher) in CRS dose experiential learning activities on force and motion systems. Black intermediate learners responded to six context-rich problems on momentum, impulse and force concepts with mean scores of 3.75, 4.17, 5.08 at lower, moderate, and higher CRS

dose levels of force and motion activities. Non-black intermediate learners responded to six context-rich problems on momentum, impulse and force concepts with mean scores of 4.28, 5.81, 5.66 at lower, moderate, and higher CRS dose levels of force and motion activities. Scores for novice learners participating in lower, moderate, and higher CRS dose levels of force and motion activities were 4.90, 4.58, 4.72 for novice blacks and 4.90, 4.42, 5.23 for novice non-blacks. Conceptual-based force and motion problems for the race (black, non-black) comparison included six problems with a focus on momentum, impulse and force concepts (PIFs). Each PIF was presented on an enlarged image media background suggestive of a contextual setting in which the problem event occurs. and allowed for learner response by selection from an array of items or objects using a mouse click. Problems were presented in a context-based media rich format with information pointers, directional arrows, supportive images, action clips, and access to hints through hypertext links.

Non-black learners seem to have a disordinal response in degree of success at both the novice and intermediate levels. Race identified as black and non-black does not appear to be a discriminator for novice learners presented with low CRS dose. Non-black intermediate learners presented with more CRS dose seem to perform significantly better than when presented with low CRS dose with learners having about the same success for both moderate and high CRS dose. And non-black intermediate learners presented with moderate to high CRS dose seem to perform significantly better than black intermediate learners presented with low or moderate CRS dose of force and motion learning activities. This suggests that learner response does vary across race (black, non-black) for intermediate learners with non-black learners performing better at higher CRS dose levels, black learners performing better at lower CRS dose levels, and non-black learners performing better overall than black learners on the force and motion problems. However, the study was not sensitive (model lacked power) to similar variations in response across race for novice learners.

**Cluster C: Visual Tools for Improving Attitudes of ACM**

C-1 (Ho 10): There was a significant difference in learner preference for technology as learning tools between learners indicated by learner level (novice, intermediate) and challenge level (momentum, impulse, force) in terms of response frequency (favorable, non-favorable) by homogeneous groups. Learner response to momentum (p), impulse (i), force (f) problem sets were matched to learner response preference (favorable (F), non-favorable (NF)) for technology learning tools. Three problems were identified for each problem set p, i, and f; responses were aggregated and scaled to identify single scores for the p, i, and f problem sets for each individual learner in the study population. Learner homogeneous group performance on problem sets (p, i, f) matched to group preference (F, NF) for technology learning tools in learning physics resulted in a spectral analysis of homogeneous learner groups portraying a fine line splitting pattern of learner responses in terms of a (F, NF) frequency of learner preferences.

Learners, novice and intermediate, were favorable (73 times out of 144) slightly more often than non-favorable (71 times out of 144) towards the usage of technology. Mean scores for learners responding favorably towards technology usage were 2.60, 2.78, 2.21 on p, i, f problem sets; mean scores for learners responding non-favorably were 3.03, 3.44, 2.52 on p, i, f problem sets. However, novice learners tended to respond favorably towards technology usage more than twice as frequently as non-favorably with mean scores of 2.87, 3.54, 2.12 on p, i, f problem sets for favorable responses and mean scores of 2.15, 2.65, 2.40 on p, i, f problem sets for non-favorable responses. And intermediate learners tended to respond favorably towards technology usage almost one and a half times as often as non-favorably with mean scores of 2.60, 2.79, 2.55 on p, i, f problem sets for favorable responses and mean scores of 3.47, 3.10, 2.50 on p, i, f problem sets for non-favorable responses.

Learners who did not favor usage of technology learning tools in the study of physics appeared to have more success in understanding momentum, impulse, and force

concepts. But novice learners responding favorable towards the usage of technology learning tools seemed to have performed better on pif problem sets (sets p and i, but not f) than those making an unfavorable response. And intermediate learners responding non-favorably towards the usage of technology in motion physics seemed to have performed significantly better on pif problem sets (sets p and i, but not f) than those responding favorably. Also, novice learners appeared to be favorable towards technology learning tools more often than intermediate learners but learners, both novice and intermediate, favoring the usage of technology learning tools seemed to have less success in understanding physics concepts about force and motion systems than did those responding unfavorably towards technology. And as the motion physics became increasingly more difficult (from p to i to f), learners seemed to have about the same success on the physics problems whether or not they indicated a favorable response towards technology learning tools.

C-2 (Ho 11): There was a significant difference in mean scores for learner confidence level (self-perception of ability to explain momentum to another) in terms of response performance on force and motion problems and CRS dose level. Mean scores for learner self-perception are indicated in terms of CRS dose level (lower, moderate, higher) and response code (right (1), wrong (-1), non-response (0)) to a less difficult shuttle launch problem and to a more difficult jet takeoff problem. Learner homogeneous group scores for a self-perception on level of confidence matched to group performance code (1, -1, 0) for two context-rich problems selected from less and more difficult problem challenge sets resulted in a spectral analysis of homogeneous learner groups portraying a fine line splitting pattern of learner responses in terms of a coded frequency (right, wrong, non-response) of learner convictions.

Learner response for the Shuttle Launch problem from the less difficult problem set matched with self-perception response across CRS dose level produced learner perception mean scores of 6.88, 6.60, 7.02 for 19 correct responses each at low, moderate and high

CRS dose levels. This same analysis scheme produced 8 wrong responses at low CRS level having a mean score of 7.27; 8 wrong responses at moderate CRS level having a mean score of 6.46; 14 wrong responses at higher CRS level having a mean score of 6.47. Non-response to the Shuttle Launch problem across CRS dose levels produced 21 non-responses at low CRS level having a mean self-perception score of 7.31; 21 non-responses at moderate CRS level having a mean score of 5.99; 9 non-response at high CRS level having a mean score of 7.52.

Learner response for the Jet Takeoff problem from the more difficult problem set matched with self-perception response across CRS dose level produced learner perception scores for 7 correct responses at low CRS level having a mean score of 8.30; 15 correct responses at moderate CRS level having a mean score of 6.76; 18 correct responses at high CRS level having a mean score of 7.26. This same analysis scheme produced 14 wrong responses at low CRS level having a mean score of 6.47; 11 wrong responses at moderate CRS level having a mean score of 6.13; 15 wrong responses at higher CRS level having a mean score of 6.58. And again the non-response to the Jet Takeoff problem across CRS dose levels produced 27 non-responses at low CRS level having a mean self-perception score of 7.17; 22 non-responses at moderate CRS level having a mean score of 6.09; 15 non-response at high CRS level having a mean score of 6.95.

Learner confidence level (perception of ability to explain momentum concepts to another) and response performance on force and motion problems seems to be influenced by CRS dose level more for less difficult force and motion problems than for more difficult problems. Learners responding to less difficult problems and making a correct response tend to have a more positive perception towards the study of science and mathematics than learners making a wrong response. However, learners electing to make a non-response seem to have a more positive science and mathematics focus that is higher than learners responding correctly. Learners responding correctly to more difficult problems seem to have a higher self-perception than if they respond incorrectly or withhold their response.

Also, learners of force and motion concepts tend to have a disordinal perception-response with dose level. Learners appeared not to respond more frequently on the more difficult problem than on the less difficult problem. They tended to make a correct response more often than a wrong response when answering the less difficult problem but seemed to make a wrong response about as frequently as a correct one when answering the more difficult problem.

There appeared to be a significant difference in the level of response (right, wrong, non-response) for the more difficult problem but not for the less difficult problem. A significant interaction between response level and CRS dose level seemed to be present for learners responding to the less difficult problem but did not appear to be significant in learner response for the more difficult problem. More importantly, learners responding correctly to the more difficult problem seemed to have a more positive perception towards the study of science and mathematics than did learners responding correctly to the less difficult force and motion problem even though learners seemed to be successful more often (17%) on the less difficult than on the more difficult problems.

C-3 (Ho-12): Assessment of learner perception towards science and mathematics was matched with learner performance on force and motion problems. The affective instrument PLC2 was used as a measure of learner perceived locus of control in science and mathematics using technology. The affective assessment instrument PLC2 included eight items that permitted sampling of learner viewpoints on science and mathematics in a technology supported environment. The eight items of instrument PLC2 are aggregated into three cluster areas describing learner self-perceptions: problem solving ability (PSA); awareness of learner progress (ALP); technology as learning tools (TLT). Matched learner performance on a selected problem from the less difficult and more difficult force and motion problem sets with the PLC2 measure was used to monitor learner perception across CRS dose levels (low, moderate, high) together with a learner response trend on specific enhanced force and motion problems from their respective challenge problem sets. Two

contextually enhanced force and motion problems were used to monitor learner conceptual response performance. The shuttle launched problem represented the contextually enhanced problem from the less difficult problem set and the jet takeoff problem represented the enhanced problem from the more difficult problem set. Learner response to the shuttle launch and jet takeoff problems were each coded as right (1), wrong (-1), or non-response (0). This nominal coding on learner response provided a way to monitor and match learner performance on conceptual force and motion problems with learner perception of science and mathematics.

There was a significant difference in mean scores for poor and good learners of science and mathematics in terms of mean scores for the problem solving ability (PSA) self-perception instrument cluster and coded response frequency to a learner confidence level probe involving a self-assessment of one's ability to explain momentum. Learner homogeneous group scores for the PSA self-perception cluster matched to a self-assessment of learner control level (yes (1), no (-1), non-response (0)) for one's ability to explain momentum resulted in a spectral analysis of homogeneous learner groups portraying a fine line splitting pattern of learner PSA scores in terms of a coded frequency (yes, no, non-response) response of learner confidence portrayed by good and poor learners of science and mathematics. Responses by poor learners to the self-assessment of learner confidence probe produced 31 positive responses having a mean score of 9.38; 8 negative responses having a mean score of 5.73; 33 non-responses having a mean score of 5.53. Responses by good learners to the same self-assessment of learner confidence probe produced 27 positive responses having a mean score of 9.29; 9 negative responses having a mean score of 7.22; 36 non-responses having a mean score of 5.90.

More learners, good and poor, responded than did not respond regarding their confidence level about motion physics. And the learners responding positively tended to score significantly higher on the problem solving ability cluster than the learners responding non-positively. More poor than good learners expressed a positive confidence

level. Slightly more good learners than poor learners decided not to risk a response. The same number of good learners responded as those that did not respond concerning their confidence level, however fewer good learners made a positive response than a non-response. Also, more poor learners responded than those that did not respond and the frequency of a positive response for poor learners was slightly less than their frequency of a non-response concerning their confidence level. However, it appears that good learners who felt less positive regarding their confidence level about motion physics tended to score significantly higher on the problem solving ability cluster than did the poor learners.

C-4 (Ho-13): There was a significant difference in mean scores for learner performance on a problem challenge set of more difficult problems between learner performance on this set scored as right, wrong (RW) and the same learner performance scored as right, wrong, non-response (RWO) as determined by monitoring the response to a jet takeoff problem from the same problem set. Learner homogeneous group scores for the MD2 problem challenge set scored as RWO and again as RW and matched to responses of novice and intermediate learners on a selected problem (right (1), wrong (-1), non-response (0)) from the same problem set again resulted in a spectral analysis of homogeneous learner groups portraying a fine line splitting pattern of learner scores in terms of a coded frequency response (right, wrong, non-response) to a problem taken from the same problem set.

Responses by novice learners to the force and motion problem set MD2 scored RWO produced 20 correct responses having a mean score of 6.40; 21 wrong responses having a mean score of 5.30; 31 non-responses having a mean score of 3.47; and for the same problem set MD2 scored RW produced 20 correct responses having a mean score of 6.63; 21 wrong responses having a mean score of 5.95 and 31 non-responses having a mean score of 5.48. Responses by intermediate learners to the force and motion problem set MD2 scored RWO produced 20 correct responses having a mean score of 6.77; 19 wrong responses having a mean score of 5.99; 33 non-responses having a mean score of

3.37; and for the same problem set MD2 scored RW produced 20 correct responses having a mean score of 6.92; 19 wrong responses having a mean score of 6.27 and 33 non-responses having a mean score of 5.38. Both novice and intermediate learner groups exhibit a significant score shift on the MD2 problem set for learners indicating a non-response to the jet takeoff problem when the same problem set is scored in terms of a binomial response (RW) and again in terms of a trinomial response (RWO).

This analysis shows that the non-response code seems to significantly affect indicated learner outcome when learner non-response is scored as a wrong response rather than as a non-response in the assessment instrument. The non-response code seems to significantly affect the response pattern for both novice and intermediate learners monitored by their response to a specific problem contained within the assessment instrument. Plots of mean responses for type score and response code for the specific problem (jet take off) seem to indicate a similar disordinal response pattern for both novice and intermediate learners. Mean scores for learners making a conviction seem to be somewhat higher for intermediate learners than for novice learners; and mean scores for learners having no conviction seem to be about the same for novice and intermediate learners. Mean scores on the instrument (RWO) scored in terms of the presence of a non-response indicate a wider spread than on the instrument (RW) scored ignoring the non-response of homogeneous learner groups as a separate code category. The instrument scored RW assigned learner non-response to the wrong response category in a way that total learner responses were conserved for computation of mean scores on the two assessment instruments. As a result, the instrument scored RW presents averages for the non-response code separate from the wrong response code in the same manner as the same instrument scored RWO for the sake of evaluating the non-response effect on the overall assessment instrument. Hence the wrong response mean values for the instrument scored RW would in fact be plotted somewhat higher than is apparent in the graphs but lower than the correct response mean values.

The case presented for this analysis included about the same learner count for each learner group (novice, intermediate) in each response code category (RWO: right, wrong, non-response; and RW: right, wrong). Notice that although a majority of learners (about 56%) indicated a conviction (right or wrong) regarding the jet take off problem, a significant number of learners (about 44%) elected not to risk a response or otherwise failed to make a conviction regarding this problem. The instrument scored RW represents a common and traditional way of assessing student performance as a traditional binary response outcome (right, wrong) rather than allowing for additional categories such as is present in a more plausible trinomial response outcome (right, wrong, non-response) as indicated by the same instrument scored RWO. One must consider that the assignment of a large non-response group to the wrong response code category has certain potential for misguiding decision-making concerning curriculum programs and career directions. Perhaps a re-evaluation of the purposes and fairness in which assessment instruments are scored is in order. At the very least, research studies should be open to usage of additional response categories when assessing and evaluating results from different study populations of learners (Appendix I, Figures I-12 to I-14; Appendix J; Appendix M, Figure M-4).

**Cluster D: Nurturing a Progression of Learners towards Success as ACM**

The study population included a community of learners identifiable as novice, intermediate and expert learners of science and mathematics. Since physics students participated as expert learners in all facets of the study, they provided a more expert-like response (MER) for focusing the response of novice and intermediate learner groups. Hence homogeneous learner groups are suggestive of a progression of learners (novice and intermediate; poor and good) over time on the road toward mastery (MER) of underlying concepts involving momentum, impulse and force operating within force and motion real world systems (Appendix M, Figures M-2, M-3, M-6).

D-1 (Ho-14): There was a significant difference in learner performance on cognitive and affective measures of learner behavior due to having received CRS type

experiential learning activities on force and motion systems about momentum. Repeated measure responses of novice learners by learner type (12 poor, 12 good) to three sets of force and motion problems (one written and two electronic) across CRS dose level produced mean scores for poor learners of 6.47 at low CRS level, 6.15 at moderate CRS level, 6.51 at high CRS level for 36 responses each; and mean scores for good learners of 6.98 at low CRS level, 6.97 at moderate CRS level, 6.50 at high CRS for 36 responses each. Repeated measure responses of intermediate learners by learner type (12 poor, 12 good) to three sets of force and motion problems (one written and two electronic) across CRS dose level produced mean scores for poor learners of 6.18 at low CRS level, 6.11 at moderate CRS level, 6.56 at high CRS level for 36 responses each; and mean scores for good learners of 6.63 at low CRS level, 6.85 at moderate CRS level, 6.90 at high CRS for 36 responses each.

Repeated measure responses of novice learners by learner type (12 poor, 12 good) to three sets of expectation measures across CRS dose level produced mean scores for poor learners of 7.02 at low CRS level, 6.50 at moderate CRS level, 7.40 at high CRS level for 36 responses each; and mean scores for good learners of 8.09 at low CRS level, 7.07 at moderate CRS level, 7.51 at high CRS for 36 responses each. Repeated measure responses of intermediate learners by learner type (12 poor, 12 good) to three sets of expectation measures across CRS dose level produced mean scores for poor learners of 7.23 at low CRS level, 6.31 at moderate CRS level, 7.34 at high CRS level for 36 responses each; and mean scores for good learners of 7.48 at low CRS level, 5.63 at moderate CRS level, 6.31 at high CRS for 36 responses each.

Both poor and good novice learners exhibited a disordinal response by CRS dose level in success outcome on cognitive force and motion measures. Intermediate learners likewise seem to exhibit a disordinal success response, with good learners having greater success from moderate to high CRS dose levels and poor learners having lesser success from low to moderate CRS dose levels. Novice learners seemed to achieve their greatest

success on cognitive measures at a low to moderate CRS dose level with good learners performing better than poor learners. Intermediate poor learners experienced the least success at low to moderate dose levels and intermediate good learners performed better than poor learners. Success for intermediate learners on cognitive measures of force and motion concepts seems to be significantly greater at all CRS dose levels for intermediate good learners than for poor learners.

Both poor and good novice learners exhibited a disordinal response by CRS dose level on affective measures of learner expectations towards science and mathematics; however, novice good learners did seem to make a favorable response more often than novice poor learners. Intermediate learners likewise seemed to exhibit a disordinal response pattern across CRS dose levels with good learners making a favorable response less often than poor intermediate learners. Novice learners seem to respond favorably on affective measures at low to moderate CRS dose levels, with good learners making a favorable response more often than poor learners. Also, intermediate poor learners seemed to respond favorably more often than intermediate good learners on learner expectations towards science and mathematics.

Conceptual force and motion problems (pifs) presented to the study population were grouped into three main categories (written (5), electronic_1 (8), electronic_2 (13)); the average response for each homogeneous learner group determined for each of the problems in a given problem category; and this average response entered into the analysis of variance as a repeated measure of the appropriate homogeneous learner group assigned to one of three CRS dose treatment levels (A,B,C) on the cognitive domain. All scores were scaled to an index of 10. Cognitive domain scores are of course matched to affective domain scores for subjects in each of the homogeneous learner groupings.

Learner expectations in science and mathematics (spexs) collected on the study population were grouped into three main categories (SMT (3), PLC1 (6), PLC2 (8)); the average response for each homogeneous learner group determined for each of the queries in

a given expectation category; and this average response entered into the analysis of variance as a repeated measure of the appropriate homogeneous learner group assigned to one of three CRS dose treatment levels (A,B,C) on the affective domain. All scores were scaled to an index of 10. Affective domain scores are of course matched to cognitive domain scores for subjects in each of the homogeneous learner groupings.

The research design identified a total of twelve homogeneous learner groups with twelve subjects per group. Since each subject is treated as a repeated measure for a specific learner group, twelve repeated measures were recorded for each homogeneous learner group. Learners were aggregated according to being good or poor learners of science and mathematics, being at the novice or intermediate level of formal schooling, and being in one of three CRS dose treatment levels. Also an expert group was identified for the study and members of this group performed all activities in the same way and during the same time period that the study population underwent treatment.

D-2 (Ho-15): A sufficient number (>11) of the fifteen test hypothesis used in this research study were found to be significant by the laws of probability for the binomial theorem. The research designer model is considered validated for the target study population of learners on which it has been tested. Future investigative research involving a more extensive population of learners would provide an opportunity to further assess learner behavior patterns (i.e., identify how similar or dissimilar replication of some larger community of learners might be from what has been expressed through the research design model by the more limited population of learners used in this research study). Continued research opportunities for applications of the research designer model would provide additional learner behavior measurements, an opportunity for monitoring to what extent other learner populations might deviate from the observed target population of learners used for this study as well as how the current target population might change over time with continued intervention procedures.

The research designer model has provided an opportunity to explore a collection of factors that might be considered pertinent to procedures for making learning stuff more understandable to a given learner population; thereby, finding ways to focus and raise the level of learner success and to better allow opportunities for learner growth in a technology supported environment. The study hypotheses tested can be summarized into four types of model building tools: (A) visual tools for inspiring analysis (VTIA-1: Ho 1,2,7,10,11) by analytical caring minds in a way that leverages context for concept development; (B) identifying with diverse learner groups (IDLG: Ho 3, 4, 12, 13) as sources of analytical caring minds; (C) visual tools for improving attitudes (VTIA-2: Ho 5, 6, 8, 9) of analytical caring minds; (D) nurturing a progression of learners toward success (NPLS: 14, 15) as analytical caring minds.

Ideally, this research study has focused on modeling tools for identifying learner success and focusing learner progress towards a more expert-like response, thereby allowing more learners passage to higher levels of achievement. Learner growth patterns can and should be modeled and monitored in interesting and creative ways that would favor pushing the cognitive profile behaviors of learners in a way that could promote and accelerate their passage to higher levels of cognitive learning. Models provide tools not only for monitoring a given learner endeavor or state of functioning but also for focusing and sharpening learner behaviors in ways that provide opportunities for them to seek success at higher challenge levels of complex cognitive thought. More importantly, this research study suggests a learner cognitive profile approach that seeks to identify and develop tools for monitoring and promoting the intellectual growth of a community of diverse learners in ways that may be more likely to enhance and extend current boundaries of human intelligence.

## Research Model Extensions – Success Goals

### Building Success Opportunities for Learners

Focusing learners towards success goals can be visualized in ways that ascertain an extent of learner control, effort, conviction, success in terms of some referent system representative of goal achievement or mastery. Such focusing systems can be regarded as guiding or channeling the learner toward the light at the end of the tunnel by positioning the learner in some apprenticeship role. And the system may be thought of as referencing the response of the learner to that of a more expert-like response for the sake of identifying a progression of learners on a journey toward success, that of an expert referent response. Focusing tools serve to orient and direct learner's efforts toward visible and tangible learning goals and achieving objectives desirable for concept development. Positioning and focusing learners for success involves finding ways to invoke a response from the learner and help the learner improve the response in a way that the learner becomes more expert-like.

Invoking a response from a learner means that in someway the learner comes by a conviction regarding what is being studied and shares this conviction with others. This response process involves several steps that need to be acted out by the learner. One needs to consider what prompts the learner to make a response in the first place as opposed to withholding a response. The response process requires the learner to be in control of learning in a way that the learner is capable of forming and expressing a conviction, willing to take a risk and share that conviction with others, and willing to put forth the effort that make all this happen. This suggests that the learner needs to identify with some vantage point that makes the learner's self-expression of a point of view worthwhile in a way that the learner feels a response has some value and opportunity for being received and accepted at some level by others. Learner control of learning can be perceived on two levels that involve learner effort and learner integrity. The learner's self-perception of an ability to respond depends on how much the learner feels in control of the learning environment and

the amount of effort the learner is willing to make in forming a response. And the learner's perceived response depends on the learner's value system for making an honest response as shaped by the learner's orientation, attitude and cognitive profile towards the activities, program, and curriculum being presented.

A first step towards invoking a learner response involves the learner being willing to risk a response in terms of what is at stake for the learner and of what the learner values as being worth the risk. The learner elects to respond or not to respond and makes a conscious decision whether or not to form a conviction and share this conviction with others. A second step is that of the learner willing to put forth the effort required of the learner in order to form convictions and make a response. The learner needs to identify with some kind of internal or external incentive for responding and the learner needs to pull from some kind of informed knowledge base in order to form a conviction and make a response. The learner must engage in a conscious effort to decide what is true or untrue, what is right or wrong, whether to elect to agree or disagree, whether to make a favorable or an unfavorable response. A third step involves the learner weighing in what light the response will be presented, how much relevant information will be put forth, and whether or not this information presented will be what the learner in someway feels and knows to be the case. The learner carries a certain degree of integrity and honesty in shaping a response depending on what is desired that others might know about how the learner thinks or perceives that something is or is not the case and why the learner might possess belief in some knowledge. Once the learner elects to make a response, the learner elects how to respond, which may or may not be intended as an honest response. More clearly, learner response is a matter of learner integrity aligned with a self-possessed value system used for deciding how much of the truth which the learner knows does the learner want others to know too. A fourth step involves the learner weighing the risk of response in terms of elements in the environment that either tends to welcome a response or otherwise threaten and thereby inhibit a response from the learner. The learner tends to compare outcomes

more in terms of the relative risk of receiving a penalty for responding in a less than correct way or being less than perfect when faced with a competitive environment. Conversely, the learner would value a response outcome as part of the trial and error process on the road to success in an environment that facilitates learning and provides non-threatening opportunities for learning.

Knowledge of the extent of learner response versus non-response is required for guiding learners toward successful outcomes. And such systems of response, non-response and success, non-success need to be studied in order to better understand how learners go about making convictions, why they make them, and how they might be encouraged to make a conviction shift or change that would be more expert-like than previously held. Four index factors important to the response process, identified through this discussion, and explored in this research study are a response factor, an integrity factor, a conviction factor, and a conviction shift factor. Engaging studies on learner success needs ways to monitor learner performance and progress towards definable goals such as learner response to a dosage scheme of information presentation on a gradient scale from less to more which contributes in some way towards enhancing and extending the learning experience. Desired ways for detecting and recording learner response needs to be identified and this collected data organized in a way that characterizes the response pattern of a study population. More importantly, learner response shifts, events and tools that assist learners in making a response shift, and experiences that might be regarded by the learner as being fruitful and hence worthy of desired response shifts need to be identified. These type of learner behaviors need to be studied in order to shape and implement a more meaningful learning experience for learning communities, grow learners more capable of forming convictions, and cultivate a sense of integrity for and commitment to the learning experience.

The work, presented by this researcher, models a process for accomplishing the task of shaping, sculpting, and growing better thinking communities of learners. A

learning community is modeled as being on an active quest for thinking about the world and its events in a way that draws out learner enthusiasm, excitement, involvement and stimulates learners to contribute, engage, build, explore, explain and create new ways of knowing. Learners of science and mathematics need special tools that help shape analytical caring minds for handling complex mental processes required of them while problem solving. Context-based visual tools for learning in ways that help the learner better extract information, identify the concept, and carry a message have been modeled and demonstrated through this study. This study has focused on creating an array of learning wells for a spectrum of learners. This study models and suggests the usage of technology as enhanced tools for sculpturing learner thought patterns in ways never before dreamt for improved learner performance and learner success in science and mathematics. This study has only begun to touch on the numerous possible pathways to learner success. Many questions lie in its wake to better shape future learning opportunities. Just a couple of questions suggestive of imperative directions from which to carry the current findings and modeling concepts are concerned with learner stimuli analysis. One might ask to what extent are stimuli designed to focus learner attention toward success competing with the myriad of stimuli of one kind or another which act as learner distractions from engagements of fruitful learning experiences? And one might even challenge the usage of accepted learner stimuli asking whether stimuli intended for positioning the learner for success do in fact perform this function? Or perhaps, do they need further modification to interface more effectively in rapid changing learning environments; are there other more effective and efficient stimuli available or that could be constructed for performing this function? Additionally, one can ask what kinds of things can be done to stimulate learners to value positive learning experiences. One might ask how might one broadcast these value strategies to learning communities at large; how might political processes within the community be moved to provide visible support required for desired learning values to survive and prevail over learning distractions? Only through continued, constant, and

vigilant monitoring and analysis of changing learning environments can researchers hope for the support of resources and opportunities needed to address and find answers for questions as these. Learning is a vital thread within the human fabric of societies and a necessary ingredient for maintaining, cultivating and growing the web of life for a better and more peaceful tomorrow.

The motto for this study has been that doing merits being and hence existence; doing fosters and shapes learner esteem; doing molds attitudes, abilities, aptitudes into a whole new attire for being and becoming. Today, possibilities abound for learners not only to dream but also to see and work with their dreams in action. Learners can enter plausible worlds of virtual land and compare their surrealistic experiences with familiar real world happenings. Possessing new stimuli for making connections in the real world will allow learners to more easily bring their dreams into reality to be lived out, merged with other dreams, and extended into future dreams. As the learning experience evolves and matures, more studies using research designer modeling tools will be needed to better understand and micromanage opportunities for new ways of learning. This researcher hopes that this research study may provide helpful methodologies for these kind of future studies.

**Demonstration of a Progression of Learners towards ERR: Cognitive**

The learner progression is applied to learner responses on one of the instruments assessing learner understanding of momentum, impulse and force as presented through the learning tasks engaged during treatment. This instrument is labeled TD2 in the following discussion. Each learner in each of the fifteen identified homogeneous learner groups responded or withheld from responding to each of the thirteen items on instrument TD2. This allowed for a total of 2340 responses and non-responses from the study population on instrument TD2 of which 1727 responses were observed. Hence the overall non-response level of the study population to TD2 is set at 26% (613) with 74% of the population having some kind of conviction, right or wrong. Of the 1727 responses, 45% (776) were scored

right and 55% (951) were scored wrong. This demonstrates an overall learner success rate of 33% from the study population on instrument TD2. The remaining 67% of the population either responded wrong (41%), or did not respond at all (26%). This response pattern indicates that learner response tended to be correct more frequently than wrong and that learners tended to have a conviction more often than not.

Learner success indices and learner progression graphs were constructed from data collected on cognitive instrument TD2. Learner success indices were constructed in two ways for these graphs and are described for each type of graph. One type of graph looked at learner performance by CRS dosage referenced to an expert referent response (ERR) under the same conditions for each learner group along a journey depicting learner growth from less to more experienced in science and mathematics towards a more expert-like response. Another type of graph looked at learner performance by learner group with each referenced to its response at the higher CRS dose, level C, along a continuum of CRS dosage from low to high. There exist about nine versions of these kind of plots utilizing research design variables describing performance of homogeneous learner groups in the study population that can be constructed for each of the study's assessment instruments (cognitive and affective). Three of these learner progression type graphs for cognitive measures are illustrated in Figures 6-1, 6-2, 6-3 and discussed in the following passages.

The journey to success can be studied first from the graph in Figure 6-1 which shows three plots of learner responses to instrument TD2, one for each of the CRS dose levels used in this study (A<B<C). The plotted points, from right to left, of learner indices occur at three stages of learning: expert (E), intermediate (I), and novice (N). The journey is made to occur from right to left, with learner age in science and mathematics normalized to the average expert age of the high school physics groups. And each of the three pathways to success identified with one of the three discrete dose levels of CRS activities presented during treatment. The learner relative success (RS) for being more expert-like in knowledge on each pathway for each learner level (novice, intermediate) is referenced to an

expert response observed at the corresponding CRS treatment level (RS_A, RS_B, RS_C). The expert focal point is positioned in the upper left corner of the graph at position (0,1) and serves as a beacon of light for learners on the journey to success. Learner success indices were computed as odds ratios of learner success (right response frequency divided by wrong response frequency) at a given learner level and CRS dosage to the expert success (right to wrong responses) at the same CRS dosage.

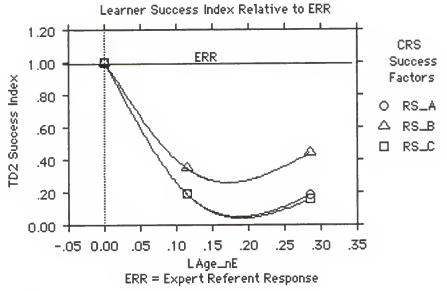



Figure 6-1.
Learner Progression over Time at Three CRS Dose Levels on Problem Set TD2. (Learner age determined by formal level studied in science and mathematics; TD2 score relative to an Expert Response (ERR) at each CRS Dose Level.)

The graphs presented in Figure 6-1 indicate that responses of both novice and intermediate learners were significantly outdistanced by the expert response. Also, learners, both novice and intermediate, at CRS dosage level B performed better than learners having levels A or C with the latter learners performing about the same. The graphs also indicate that novice learners (good plus poor) performed slightly better than intermediate learners (good plus poor) when presented with dose level B; however, the

CRS treatment does not seem to discriminate on learner response (novice versus intermediate) for learners at dose levels A and C.

The journey to learner success illustrated in Figure 6-1 is further expanded by graphs presented in Figure 6-2 which delineate on learner age in science and mathematics for poor and good learners within each of the levels novice and intermediate. The process of constructing the pathways is repeated except that each pathway now has four points in addition to the expert point describing a learning journey relative to level of CRS treatment. The expert focal point is likewise in the upper left corner of the graph at position (0,1) and serves as a light beacon for learners on the journey to success. Figure 6-2 again indicates relative positioning of learners (novice poor, novice good, intermediate poor, intermediate good) relative to an expert response however the pathways are more defined. Dividing learner response into poor and good categories at novice and intermediate learner levels indicates subtle differences not observable previously. The more successful group from CRS level B indicates a threshold hill that learners mount in the early ages of the journey and that later on a dip in success occurs as the learners pass through a valley from which they rise to enjoy greater success, yet significantly beneath that of the local experts from their own community of learners. The less successful groups from CRS levels A and C appear to become intertwined along their pathways to success and caught on a plateau until a point later in time at which a response shift appears to be made as the learners begin a hopefully rapid climb out to higher ground towards the expert beacon. Still the response pattern indicates there is much work to be done, and preferably early on, if there is to be hope for the majority of learners to attain a more reasonable level of expert status on basic concepts of momentum, impulse and force found in force and motion systems.

Once more the journey to learner success is visualized but this 'for instance' considers more the effect of CRS dosage rather than learner age as a tool for identifying learning pathways. Each of the five learner groups in the study population are identified

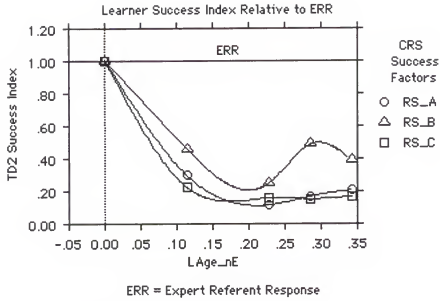



Figure 6-2.
Learner Progression over Time at Three CRS Dose Levels on Problem Set TD2. (Learner age determined by formal level studied in science and mathematics; TD2 score relative to an Expert Response (ERR) at each CRS Dose Level.)

with each of the five graphs in Figure 6-3. Success indices are computed from odds ratios of learner success (right to wrong response frequency ratio) at a given dose level (A, B, or C) for a given learner group referenced to learner success observed for that same learner group at CRS dose level C. This means that each learner group is challenged to self-mastery by the response of that group coming from level C. Although the expert response does not compute directly into the odds ratios for the other learner groups, an ERR threshold for learner success can be identified for these graphs. The CRS dose levels (A<B<C) from right to left along the ordinate axis act as anchor points, identifying responses for each learner group. Dose levels are normalized on the dosage of CRS activities at the higher level, level C. The overall effect of this graphical layout focuses learner sights on mastery referenced to self as well as to an expert response level for each level of CRS dosage. The plots, illustrated in Figure 6-3, have a blimp-like surface bounded by the poorer learners, intermediate on the high side and novice on the low side,

with good learners on nearly a direct path towards mastery with increasing dosage of CRS. One group, the novice good learners at low CRS dose (level A) broke through the ERR ceiling, outperforming novice good learners at moderate to high CRS dose levels. The other learner groups, novice poor and intermediate poor and good, indicate their greatest success resulted from CRS dose level C relative success indices for levels A and B. The expert learner groups appear to have no response difference due to the three CRS dose levels used in this study and taken together they serve to identify a higher, mastery response level, ERR, for learners associated with each of the dose levels (A, B, C).

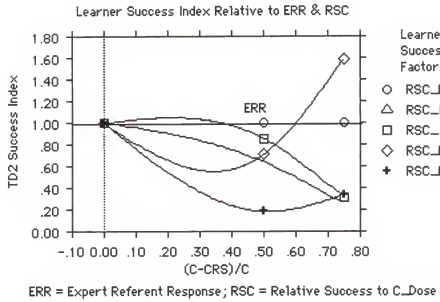



Figure 6-3.
Progression of Learner Response on Problem Set TD2 over CRS Dose by Learner Group (IG, IP, NG, NP, EG; CRS Dose relative to Level C; TD2 Index relative to Group Score at Level C.)

Important to the design of this research study has been the inclusion of an internal expert response at each of the treatment levels and under all of the same conditions experienced by the other less-experienced learner groups participating in this study. This local expert-like response coming from the same community of learners as the study population provides a greater degree of validity for the assessment instruments associated with this study, serves as a gauge for the level of accomplishment by less-experienced

learners, and allows for focusing each of the varied learner groups towards success. Since the expert learners act as in internal standard to the study, less emphasis can be made to external standards in terms of norm referencing learner performance. And the local expert response helps to make arguments for mastery goal attainment of the other learners more plausible. This modeling approach may allow research studies to become more precision-tuned and sensitive to effects invoking learner response shifts and may suggest better methods for supporting those shifts towards mastery.

**Demonstration of a Progression of Learners towards ERR: Affective**

Learner favorable indices and learner progression graphs were constructed from data collected on affective instrument PLC2. Learner favorable indices were constructed in two ways for these graphs. One graph looked at learner performance by CRS dosage referenced to an expert referent response (ERR) under the same conditions for each learner group (NP, NG, IP, IG) using an odds ratio of learner odds to expert odds along a continuum of learner development from less expert-like (NP) to more expert-like (EG). Another graph considered learner performance by learner group with each referenced to the response of that same group at a higher CRS dose, level C, along a continuum of CRS dosage from lower (A) to higher (C).

The progression of learners towards a more favorable expert-like response is illustrated from three graphs in Figures 6-4, 6-5, 6-6. The first graph (Figure 6-4) shows three pathways of learner responses to instrument PLC2, one for each of the CRS dose levels used in this study (A<B<C). The plotted points, from right to left, of learner indices occur at three stages of learning: novice (N), intermediate (I), and expert (E). Learner age in science and mathematics is normalized to the average expert age of the high school physics groups and each of the three pathways to a more favorable response are identified with one of the three fixed dose levels of CRS activities presented during treatment. The learner relative success (RS) for being more favorable in attitude on each pathway for each

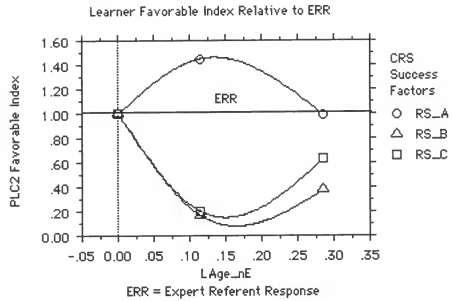



Figure 6-4.
Learner Progression over Time at Three CRS Dose Levels on Expectation Set PLC2. (Learner age determined by formal level studied in science and mathematics; PLC2 score relative to Expert Response (ERR) at each CRS Dose Level.)

learner level (novice, intermediate) is referenced to an expert response observed at the corresponding CRS treatment level (RS_A, RS_B, RS_C). The expert focal point is positioned in the upper left corner of the graph at position (0,1) and serves as a beacon of light for learners on the journey to a more expert-like response. Learner favorable indices were computed as odds ratios of learner success (agree response frequency divided by disagree response frequency) at a given learner level and CRS dosage to the expert success (agree to disagree responses) at the same CRS dosage. Graphs presented in Figure 6-4 indicate that responses of both novice and intermediate learners were significantly outdistanced by the expert response along pathways for RS_B and RS_C but not for RS_A. Learners at CRS dosage level A responded as favorably (novice) or more favorably (intermediate) than the experts responding at level A and better than learners at levels A or C with novice learners at C being more favorable than novice learners at B. The graphs also indicate that novice learners (good plus poor) seem to be more favorable than

intermediate learners when presented with dose levels C and B and less favorable when presented with dose level A. The CRS treatment does not seem to discriminate on intermediate learner response at dose levels B and C.

The journey to learner success illustrated in Figure 6-4 is further expanded by graphs presented in Figure 6-5 which delineate on learner age in science and mathematics for poor and good learners within each of the levels novice and intermediate. The process of constructing the pathways is repeated except that each pathway now has four points in addition to the expert point describing a learning journey relative to level of CRS treatment. The expert focal point is likewise in the upper left corner of the graph at position (0,1) and serves as a light beacon for learners on the journey to success. Graphs for Figure 6-5 again indicates relative positioning of learners (novice poor, novice good, intermediate poor, intermediate good) relative to an expert response however the pathways are more defined. Dividing learner response into poor and good categories at each learner level, novice and intermediate, indicates subtle differences not observable previously. The more successful group from CRS level A indicates a threshold hill that learners mount in the early ages of the journey (NG) and that later on a dip in success occurs as the learners pass through a valley from which they rise to enjoy greater success yet significantly beneath that of the local experts from their own community of learners. The less successful groups from CRS levels B and C appear to move from being more favorable to even less favorable along their pathways to success that dips to a low (IG) in need of a response shift for learners to make a rapid climb out to higher ground towards the expert beacon. The response pattern indicates there is much work to be done, and preferably early on, if there is to be hope for the majority of learners to attain more favorable attitudes towards becoming more expert-like in their responses toward their learning experiences in the sciences and mathematics.

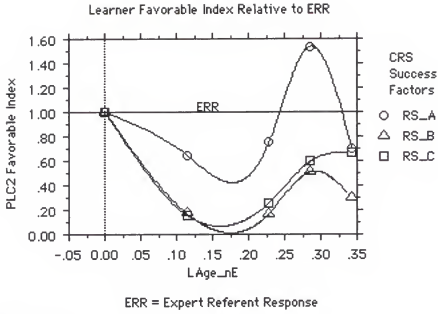



Figure 6-5.
Learner Progression over Time at Three CRS Dose Levels on Expectation Set PLC2. (Learner age determined by formal level studied in science and mathematics; PLC2 score relative to Expert Response (ERR) at each CRS Dose Level.)

The journey to learner success of a more favorable expert-like response is visualized in Figure 6-6 as a 'for instance' that considers more the effect of CRS dosage rather than learner age as a tool for identifying learning pathways. Each of the five learner groups in the study population are identified with each of the five graphs in Figure 6-6. Success indices are computed from odds ratios of learner success (right to wrong response frequency ratio) at a given dose level (A, B, or C) for a given learner group referenced to learner success observed for that same learner group at CRS dose level C. This means that each learner group is challenged to self-mastery by the response of that group coming from level C. Although the expert response does not compute directly into the odds ratios for the other learner groups, an ERR threshold for learner success can be identified for these graphs. The CRS dose levels (A<B<C) from right to left along the ordinate axis act as anchor points, identifying responses for each learner group. Dose levels are normalized on the dosage of CRS activities at the higher level, level C.

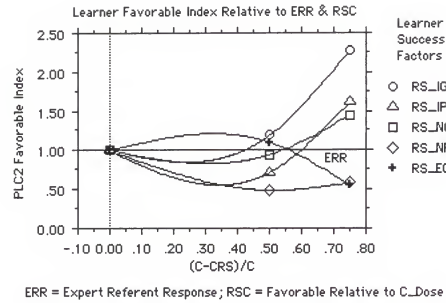



Figure 6-6.
Progression of Learner Response on Expectation Set PLC2 over CRS Dose by Learner Group. (IG, IP, NG, NP, EG;CRS Dose relative to Level C; PLC2 Index relative to Group Score at Level C.)

The overall effect of this graphical layout (Figure 6-6) focuses learner sights on mastery referenced to self as well as to an expert response level for each level of CRS dosage. Response for the experts seems to be lower at level A than for that at levels B or C which are about the same. However, expert groups at levels B and C serve to identify a mastery response level, ERR, for learners associated with each of the dose levels (A, B, C). All learners but the NP learner group seem to have broken through the ERR ceiling at CRS dosage level A; although the NP learner response at level A was as favorable relative to the NP response at level C as the expert response at level A was to that at level C. Good learners (novice and intermediate) at level B indicate a response level about the same as their response at level C. Poor learners at level B seem to have a less favorable response than poor learners at level C; however, intermediate poor learners seem to express a more favorable response than do novice poor learners at level B relative to that at level C of CRS dosage.

Important to the design of this research study has been the inclusion of an internal expert response at each of the treatment levels and under all of the same conditions experienced by the other less-experienced learner groups participating in this study. This local expert-like response coming from the same community of learners as the study population provides a greater degree of validity for the assessment instruments associated with this study, serves as a gauge for the level of accomplishment by less-experienced learners, and allows for focusing each of the varied learner groups towards success. Since the expert learners act as in internal standard to the study, less emphasis can be made to external standards in terms of norm referencing learner performance. And the local expert response helps to make arguments for mastery goal attainment of the other learners more plausible. This modeling approach may allow research studies to become more precision tuned and sensitive to effects invoking learner response shifts and may suggest better methods for supporting those shifts towards mastery.

**Learner Progression for a More Expert-Like Response (MER): Affective**

MER-based modeling of learner response patterns can be demonstrated once more using a post affective domain assessment instrument PLC2 for illustrating learner response patterns. The affective instrument makes use of eight response items on the expectation set PLC2 that address the learner perceived locus of control over learning experiences in science and mathematics and learner response results are evaluated using conviction--non-conviction (Figure 6-7), agree--non-agree (Figures 6-8, 6-9), and agree--disagree plots (Figures 6-10, 6-11). Each plot contains a total of fifteen plotted points and each point represents a set of two values identifying response conditions for specific learner groups. These plots are characterized and their significance interpreted for added clarification of study results.

The conviction--non-conviction graph of PLC2 (Figure 6-7) shows all plotted values falling along the diagonal in that the two values for any given learner group must sum to 100% by the nature of the plot. Evident from this graph is the fact that overall learner

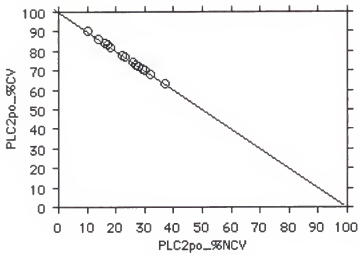



Figure 6-7.
Conviction--Non-conviction graph of Expectation Set PLC2 for Learner Groups. (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

response was reasonably high (along the upper left portion of the diagonal) indicating that learners in the study population were more likely than not to express an opinion of their control over their own learning.

Inspection of the agree--non-agree graph for PLC2 (Figure 6-8) also shows plotted values falling along the diagonal since these parameter sets also add to 100%. This graph indicates that expert groups lead the way in making responses that are favorable towards nurturing behaviors conducive to success in science and mathematics. However, two of the three intermediate good learners appear to lag behind poor learners of both novice and intermediate levels. Another version of this same graph (Figure 6-9) illustrates learner response patterns across levels of CRS dosage from low (A) to high (C). Evident from the graph is the fact that learner response to instrument PLC2 resulted in learners from four (3 at level B; 1 at level C) of the higher CRS dose levels lagging behind learners in the remaining eleven treatment groups in making responses conducive to valuing positive learning experiences in science and mathematics.

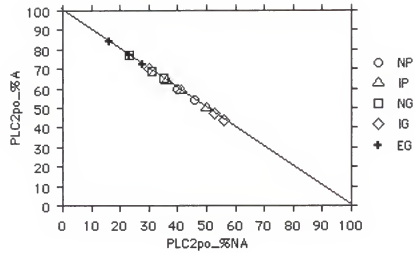



Figure 6-8.
Agree - Non-agree graph of Expectation Set PLC2 for Learner Groups (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

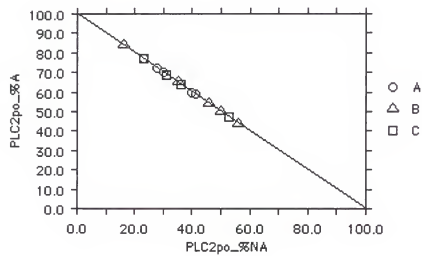



Figure 6-9.
Agree - Non-agree graph of Expectation Set PLC2 for Learner Groups at Three Discrete CRS Dose Levels A, B, C (Groups are IG, IP, NG, NP, EG)

Additional plots of agree--disagree response sets (Figures 6-10, 6-11) address the activity of learner conviction by showing more detailed comparisons of learner group responsiveness and the issue of the existence of alternative or missing responses such as the non-response. Since only three possible responses are considered for each plotted point, these graphs also allow for conservation of learner responses for a given learner group adding to a fixed value of 100%. The missing value in each set is arrived at by simply subtracting the sum of the other two for that set from 100% and this percentage is associated with a measure of a learner group's non-responsiveness. A visual reference for this third percentage as a measure of learner non-response is the perpendicular distance from the diagonal of the plotted point for any learner group. The closer a learner group point is to the diagonal, the more responsive that learner group was in expressing their perceived locus of control for science and mathematics. Once again the expert groups lead the way with the other learner groups dispersed behind the experts but aggregated in a way that younger novice learners are mixed or close to the experts and intermediate learners are not far behind. Note that all points for possible learner responses lie in the lower triangle beneath the diagonal and are bounded by (0,0), (0,100), (100,0) and the closer a group response is to the upper left corner of the allowed response region, the closer that learner group response is to that of a more expert-like response (MER).

However, three groups identified with intermediate learners, two good and one poor, lag behind twelve learner groups, three expert, three intermediate and six novice. This graph (Figure 6-10) showing measures of attitudinal learner responses suggests that, relative to an expert response, younger learners tend to respond more favorably than older learners when faced with responding to questions about perceived locus of control of ones learning after experiencing enhanced learning opportunities involving force and motion systems.

Another version of this same graph (Figure 6-11) indicates details of learner responsiveness across CRS dose level with the three tailing learner groups associated with

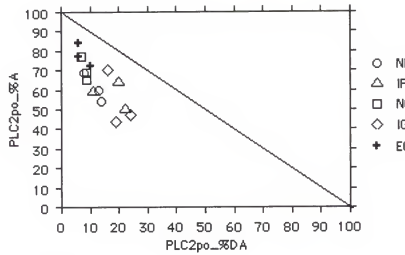



Figure 6-10.
Agree - Disagree graph of Expectation Set PLC2 for Learner Groups (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

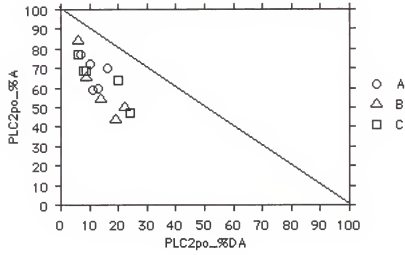



Figure 6-11.
Agree - Disagree graph of Expectation Set PLC2 for Learner Groups at Three Discrete CRS Dose Levels A, B, C (Groups are IG, IP, NG, NP, EG)

groups at treatment levels B and C. Hence the graph illustrates that, relative to an expert response, learners at lower CRS dose levels (4 groups at level A; 2 at level B) as well as higher dose levels (3 at level C) tend to respond favorably more often than some learners at higher CRS dosage (2 at level B; 1 at level C). Again, the three points plotted in the upper left corner under the diagonal indicate expert group responses and serve to visually reference other learner response patterns towards that of a more expert-like response (MER).

**Fingerprinting Learner Responsiveness: Affective**

Additional efforts can be made in understanding learner responsiveness from ways learners perceive themselves as being in control of their own learning environment and opportunities. The importance of learner perception lies in the commonly held view that people tend to think what they believe and believe what they think meaning that one's perceptions generally are closely aligned with one's beliefs. Hence, learner perceptions, inclinations, and belief structures form an important part of the picture for stimulating and measuring learner progress.

Graphical visuals prepared from learner perception data collected on the study population provide a way for studying treatment effects on learner perception in more detail. An agree-disagree (ADA) graph presented in Figure 6-12 indicates learner scores relative to a local expert response on an assessment learner expectation instrument PLC2. An agree response is measured relative to an expert response such that the response is considered a more favorable response if it is more like that of the local expert response in the study and hence potentially more acceptable for fruitful learning experiences involving science and mathematics. Three points are plotted for each learner type, each point corresponding to one of the three levels of CRS dosage used as treatment in this research study. An interesting observation is that half of the intermediate learners seem to have an overall lower locus of control towards their science and mathematics learning experiences

than do other learners. Also, learner non-responsiveness is evident by the perpendicular distance of plotted points from the diagonal line.

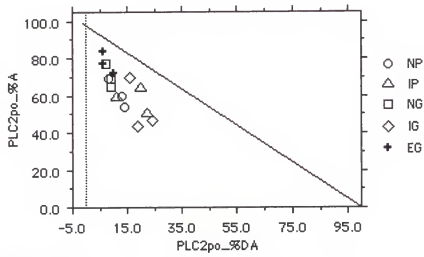



Figure 6-12.
Agree - Disagree graph of Expectation Set PLC2 for Learner Groups (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

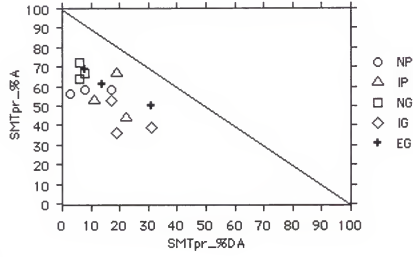



Figure 6-13.
Agree - Disagree graph of Expectation Cluster pre SMT for Learner Groups (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

Additional ADA graphs suggest how learner response patterns are distributed over four expectation clusters identified in an affective assessment instrument: science, mathematics

and technology (SMT: Figures 6-13, 6-14); problem solving ability (PSA: Figure 6-15); awareness of learning progress (ALP: Figure 6-16); and technology as learning tools (TLT: Figure 6-17).

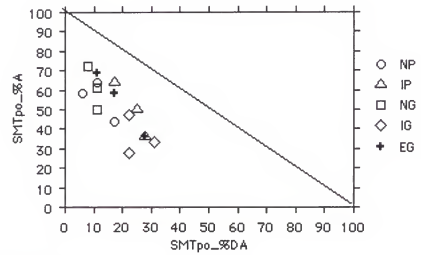



Figure 6-14.
Agree - Disagree graph of Expectation Cluster post SMT for Learner Groups. (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

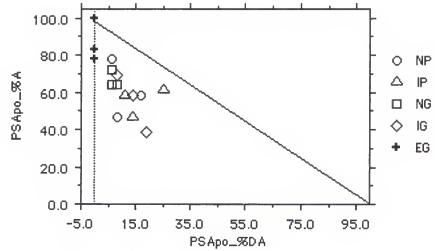



Figure 6-15.
Agree - Disagree graph of Expectation Cluster post PSA for Learner Groups. (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

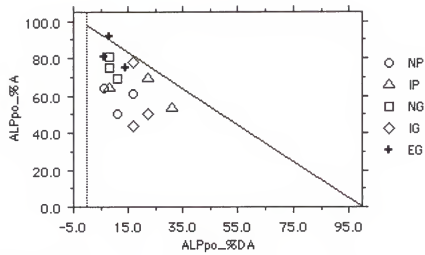



Figure 6-16.
Agree - Disagree graph of Expectation Cluster post ALP for Learner Groups. (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

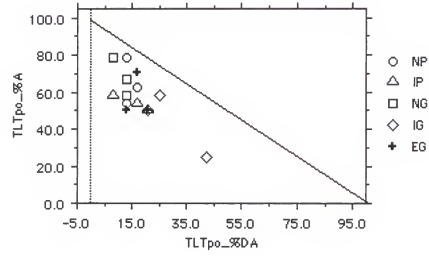



Figure 6-17.
Agree - Disagree graph of Expectation Cluster post TLT for Learner Groups. (IG, IP, NG, NP, EG; each at Three CRS Dose Levels)

Another set of graphs presented in Figures 6-18, 6-19, 6-20, 6-21 provides another way to further explore the extent to which learner perceptions are aligned with a local expert response on expectation clusters SMT, PSA, ALP, TLT at each CRS dose level. An

interesting finding from these graphs is that all learners including the local experts seem to not hold highly the usage of technology as learning tools in the study of science and mathematics.

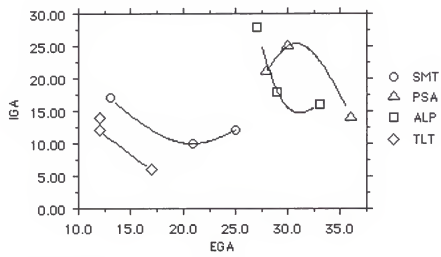



Figure 6-18.
Agree Plots with Response of Learner Group IG Referenced to Expert Response EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels.

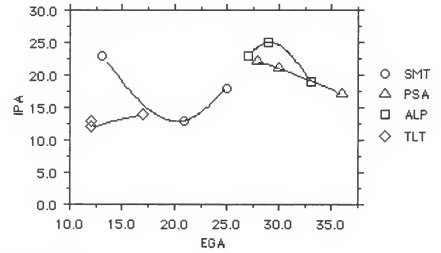



Figure 6-19.
Agree Plots with Response of Learner Group IP Referenced to Expert Response EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels.

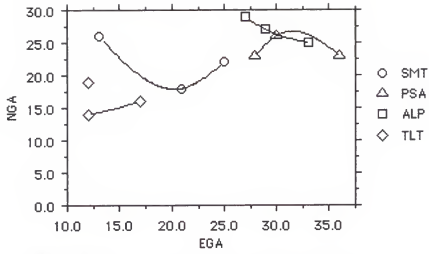



Figure 6-20.
Agree Plots with Response of Learner Group NG Referenced to Expert Response EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels.

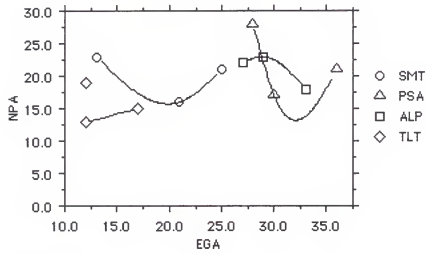



Figure 6-21.
Agree Plots with Response of Learner Group NP Referenced to Expert Response EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels.

Additional bar-graph visuals indicating scores for homogeneous learner group (NP, NG, IP, IG, EG) perceptions on learner expectations clusters (SMT, PSA, ALP, TLT) across CRS dose levels (A, B, C) are presented in Figures 6-22, 6-23, 6-24, 6-25, 6-26. These bar graphs suggest a spectral analysis of learner expectations indicated by the relative

heights of bars identifying learner response patterns over three CRS dose levels on four expectation clusters. Comparison of response patterns between learner groups (across graphs) suggests that intermediate learners appeared to respond less favorably than novice learners and expert learners seemed to respond more favorably than novice and intermediate learners on these four expectation clusters. And intermediate learners seemed to hold less favorable views than others on technology usage as learning tools with expectations of good intermediate learners being lower (less favorable) than those of poor intermediate learners. Comparison made of response patterns within learner group across CRS dosage (within graphs) suggests that novice poor learners at CRS level C relative to level A seemed to be more positive about their learning experiences in science and mathematics; while intermediate good learners at CRS level A relative to level C seemed to express a greater degree of confidence in their control of science and math related learning experiences. Also intermediate good learners at CRS dose level B expressed the lowest views concerning their problem solving abilities. And intermediate learners, poor at dose level B and good at level C, seemed to hold the lowest positive views about learning science and mathematics both within their learner group and compared to other groups in the study.

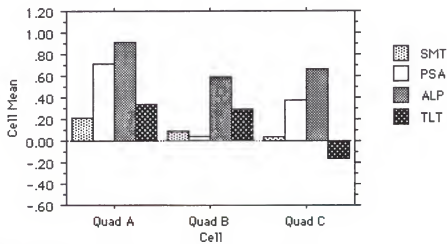



Figure 6-22.
Response Scores of Learner Group IG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

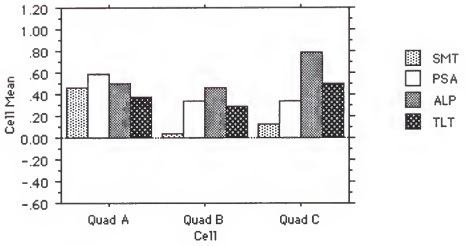



Figure 6-23.
Response Scores of Learner Group IP on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

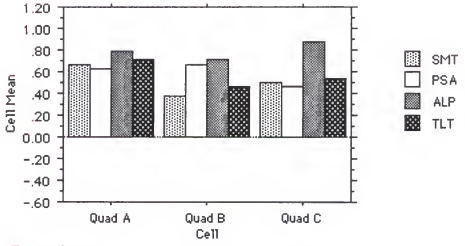



Figure 6-24.
Response Scores of Learner Group NG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

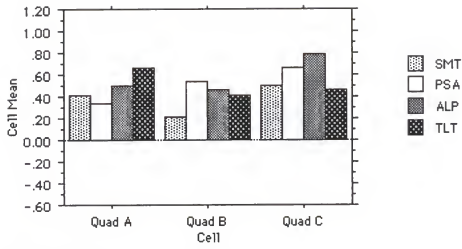



Figure 6-25.
Response Scores of Learner Group NP on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

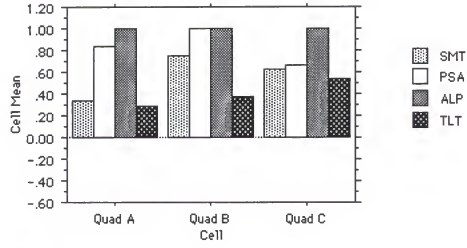



Figure 6-26.
Response Scores of Learner Group EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels (Level A at Quad A; Level B at Quad B; Level C at Quad C).

An additional set of bar-graphs illustrating more detailed spectral analysis on learner type are presented in Figures 6-22, 6-23, 6-24, 6-25, 6-26. These graphs considered two response items in each of four expectation clusters (SMT, PSA, ALP, TLT) across dose level (A, B, C) by learner ability (NP, NG, IP, IG, EG). The additional comparison layer of accounting for learner scores by cluster item produced a fingerprint type graphical

display akin to the fine line spitting of spectral lines and associated with the previous set of bar graphs. (Spectral lines refer to colored line emission and absorption patterns of analyzed light arranged from left to right by frequency or wavelength. These lines depend on excitation and absorption states (energy levels) unique to the substance being light analyzed.) These more detailed graphs are suggestive of learner energy states relative to the degree of favorable learner responses on expectation cluster items across CRS dosage. The layout of this set of graphs differs from the previous in that dose levels are grouped within response item by expectation cluster rather than expectation cluster scores grouped on CRS dose level. Since learner response is scored right, wrong, non-response (1, -1, 0), learner mean response scores can swing negative as observed on some of the response items by intermediate learners. Generally, good learners seem to respond more favorably than poor learners; but intermediate good learners appear to respond less favorably more often than other learners in this research study. And the CRS dosage effect appears to be variable depending on learner group studied. Hence, the uniqueness and variability of

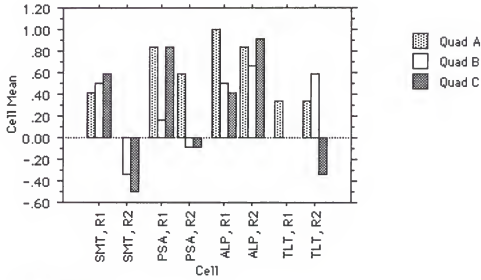



Figure 6-27.
Response Scores R1 and R2 of Learner Group IG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

learner perspectives is observable through the fine line splitting of spectral visuals such as these showing mean learner group expectations by dose level, cluster type and cluster item.

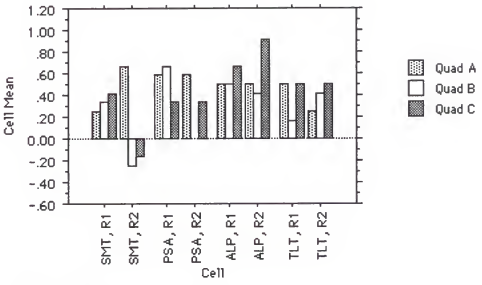



Figure 6-28.
Response Scores R1 and R2 of Learner Group IP on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

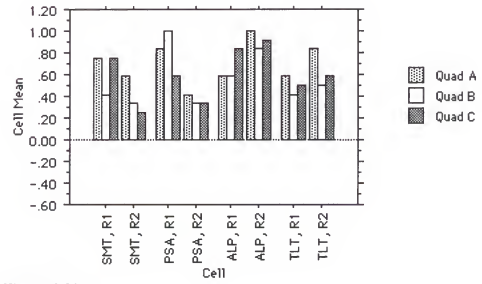



Figure 6-29.
Response Scores R1 and R2 of Learner Group NG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

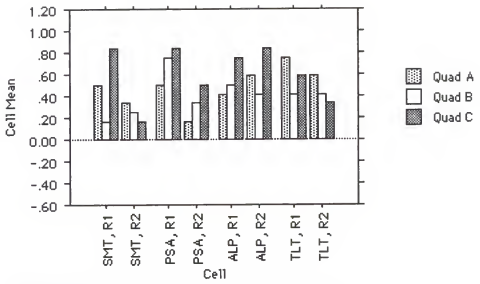



Figure 6-30.
Response Scores R1 and R2 of Learner Group NP on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

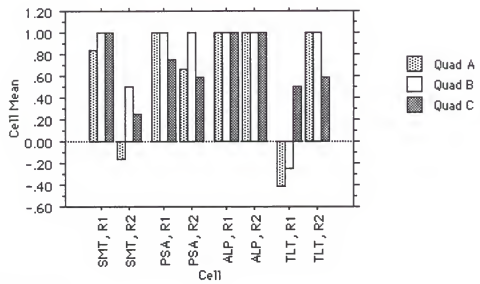



Figure 6-31.
Response Scores R1 and R2 of Learner Group EG on Expectation Clusters SMT, PSA, ALP, TLT across Three CRS Dose Levels. (Level A at Quad A; Level B at Quad B; Level C at Quad C).

Applying these research modeling tools to the modest learner data set collected in the research study has allowed this researcher to model and examine the learning progress, capability, perceptions, and interaction dynamics of diverse learners in a quest for thinking and perceiving and begin ways for describing the valley of stability of the mind, that of knowing and believing. Using the modeling tools constructed and demonstrated through this research study together with appropriate analytical thinking, future investigators may more readily identify with learning paradigms likened to the "Galaxies of the Mind" and founded on learner real world responsiveness and the probability of a success or favorable response when studying learner behaviors in problem solving situations.

## Implications and Possibilities

What has been tested through this study is a series of both subtle and complex ways of looking at the tech effect on education; ways for discovering the kinds of impact a technology supported learning environment might have on learner growth and development; and ways for guiding the content of curricula programs designed to interface learners with the new wave of rapid information delivery systems. The intent has been to develop designer research modeling tools that might allow others to better envision tech systems that work best for learner success; ways for improving learning experiences while being sensitive to possible effects of rapid change on learning communities; ways for better focusing learners through activities in changing environments promoting the rapid infusion of technology into the curricula.

A primary goal of this study was to gather, design, develop, implement, and test plausible for instances for enhancing learning activities on force and motion in ways that make the underlying concepts more understandable and interesting to the learner. Furthermore, the addition of a more expert-like response (MER) into the study suggests ways to gauge and focus directions for program modification and improvement as well as learner success. Matching learner effort against an expert referent response (ERR) familiar to their own immediate learning environment suggests goal posts that might seem more

attainable to the learner and is indicative of what might be expected in terms of learner progress on having completed a given course of study. The ERR is a ceiling on which learners can set their sights; identifies a maximum expected learner outcome to which learners might more readily relate; and provides ceiling reference for maximum possible success to aid in program evaluation and effectiveness. An ERR-like function is highly desirable for monitoring and assessing change in rapidly changing environments that promote the infusion of technology into the curricula. Interfacing rapid change technologies into classroom landscapes requires educators to become more sensitive to the diversity of learner characteristics, their tendencies towards technology usage, and what that might mean in terms of overall learner success.

Today, education desperately needs ways for understanding learner perspectives in order that each learner may be empowered to take more control and accountability for his or her own learning. Whether usage of technology today be mindful or mindless, its impact on learning communities today sets directions for learning opportunities tomorrow. Hence, guarded implementation of technology through on-going research into educational programs of today is needed least the would-be empowerment of today's learner becomes enslaved by outside controlling forces shaping tomorrows societies.

The research model evolved from this comprehensive study addresses issues and methods for identifying, monitoring, and assessing learner cognitive profiles and essential curricula design and assessment strategies with a learner focus on success in science and mathematics. The process of designing, constructing, testing strategies for context-based instruction highlighted issues dealing with both fundamental and practical concerns at the core of the instructional process. This study has emphasized a number of issues: learner conviction, perceived locus of control, identifying the problem, visual analysis, contextual referent-image systems, multi-contextual systems, tech effect, interactive multimedia, visual tools for analysis, goal focused learners, nurturing a progression of learners, modeling for learner success, motivation, trial and error, problem focus and reflection,

identifying a more expert-like response, non-ignorable non-response of homogeneous groups, cognitive-affective domain interplay, research designer modeling tools for studying diverse learner populations, methods for growing analytical caring minds, methods for identifying, describing, monitoring evolving 'galaxies of the mind'. Although this study identified and tested a total of fifteen hypotheses considering various facets of these issues, perhaps this study can be said to have raised more questions than were answered.

An example of questions raised through this study can be appreciated on considering the research model as being supportive of modeling for learner success. Indeed, this study has brought forth a number of questions: What are the factors? How does one foster learner control? How does one connect learners with concepts? What activities might learners do? What might be better ways for thinking about concepts? How might the learner discover concepts in real world happenings? How might the learner find concepts in virtual world scenarios? What are processes for utilizing virtual information systems to extract information that helps the learner make better sense of reality and even imagined worlds not yet dreamed? What processes exist for capturing analytical methodologies founded for well-established disciplines and molding these methods into new tools for better ways of thinking about building knowledge capacities and adding new knowledge to those capacities?

If growing whole new generations of learners to meet the unknown challenges of tomorrow is the change needed in the educational programs of today, then strategies are needed that can more readily assist in this enterprise of growing and focusing diverse communities of learners in ways that allow them to become more capable of mastering the challenge of the unknown hidden within vast worlds of tomorrow. The recognition of these kinds of capabilities for learning communities might just be waiting to be discovered through a better understanding of some stuff learners have called conviction.

Just think about this stuff, conviction, for a while and in the process come closer to grips of its underlying meaning. One might ask the learner to form a conviction about

some process or problem under study; the learner needs to call on a knowledge base to respond with some degree of integrity and confidence. A next step might be to ask the learner to in fact make or come forth with a conviction; this request calls on the learner to put forth some degree of visible effort and may be controlled to some extent by something called learner motivation. The learner ponders this step of making a conviction and continues onto another, that of taking a risk to share a subconscious conviction; this calls on learner stuff that might be thought of as courage or even as show-off depending on the circumstances presented.

However, the learner might ponder even further into the depths of concern over the conviction making process and its associated risks with thoughts like in what manner will this conviction requested be accepted by others; this takes a degree of learner self-confidence and will power inter-played with conditions such as the possibility of intimidation that could inhibit a response. Finally, once a learner presents a conviction to others, a judgment is bound to follow in the sense of is your conviction correct and how correct it might be; this final outcome identifies the learner with some level of success and possesses a power to suggest future directions or possible paths for continued exploration, study, discovery, and new knowledge building. The ideal of this entire discussion can be summed up in one word: conviction; i.e. learner conviction.

And if a myriad of steps can be said to pass through a learner's mind when coming forth with a conviction about some for instance, one could ask what strategies might assist a learner burdened with the task of forming, making, sharing and being judged by this thing called a conviction. Of course, the answer is problem solving strategies; and so the inquiry process, balanced with learner accountability, continues. Briefly, one version for dissecting problem solving methodology could be conceived as a six step process: 1) put the problem in context; 2) ask the question identified by the problem; 3) extract the data from the contextual representation of the problem; 4) analyze the data and find ways to make sense of the data, allowing the message carried by the data to become more

understandable; 5) draw conclusions from the data analysis that clarifies the message found within and presented by the data; 6) follow-up the problem solving process with continued inquiry leading to higher grounds for building and adding to some desired learner knowledge base.

Striving for learner success, for learners to become better problem solvers and hence better thinkers, provides essential guideposts for learners on the road towards mastery in a way that places the control for knowledge building under the learners' fingertips. Bringing learners (in touch with) closer to their own thinking processes is an essential ingredient of adaptation for learners of the next millennium as rapid information delivery systems become integrated into their everyday living experiences. Future learners of REAL world science might be thought of as reality-based expert-like accelerated learners in a world of science. Strategic tools for learning designed and implemented in a technology supported environment might be thought of as tools for molding and changing learner conviction and hence building new knowledge bases for learner success.

This study suggests ways for identifying behavioral patterns for homogeneous groups of learners attempting to discover and make sense of conceptual problem for-instances imbedded in real world scenarios; i.e. thinking opportunities. The ways in which these data from learner groups are modeled have implications far beyond the boundaries of this study. Analogous learning opportunities applied to much larger study population(s) is needed to further investigate more diverse learner outcomes and reasonable conditions through which such outcomes might be realized. The larger population study would determine what results from this study can be supported on a larger, more diverse population scale.

Continued research studies on a larger, more diverse population scale would allow for more thorough testing and modification of the strategic modeling tools identified by the current study and lend support to more extensive field applications of the CRS Model in real and virtual worlds, to identifying learner cognitive profiles in terms of the Galaxies of

the Mind Model, and to measuring a Progression of a Community of Learners towards a More Expert-like Response, MER. This would clarify and substantiate results identified in this research endeavor that may lend themselves to being generalized to other communities of learners beyond the boundary of the current study population.

Focusing learners in a study population towards a more expert-like response of force and motion concepts imbedded within their own learning community has revealed a new perspective on a more obvious conclusion. The obvious is that learners having formal training in physics curricula can be expected to more readily demonstrate their understanding of force and motion concepts. The new perspective is that the majority of learners from a learning community seem to lack, by a large margin, the comprehension of force and motion concepts when presented with new information on force and motion systems while a much higher level of understanding on concepts about force and motion systems does not seem to be a problem for fellow expert learners. Lacking formal instruction in physics, the majority of learners within a learning community seem to be far behind fellow expert learners in their level of comprehending complex mental operations related to momentum, impulse, and force needed to more fully understand and appreciate behaviors of force and motion systems.

Considering that activities for understanding force and motion concepts have been mandated at all levels of science curricula (pre-K through 12), providing only a small portion (<10%) of a school population a physics experience opportunity (students screened as ready for physics and electing to take physics as part of their secondary program) seems to be welcoming learner failure rather than promoting learner success. A possibility for better fostering the ability of novice and intermediate learners, good and poor, to appreciate and gain a more functional understanding of force and motion systems may be to provide these learners with greater opportunities for participating in secondary science physics courses and during the early part of the secondary school program, perhaps as a tenth grade physics course.

Tenth grade physics is in fact not new to science programs of the latter part of the twentieth century and much curricula addressing this need already exists. What may be said to be different about physics for secondary science programs is that now, more than ever, visual tech-tools abound to assist in clarifying physics concepts requiring complex mental processes. What this study has addressed in the usage of visual tools for better understanding science is their powerful motivational role for focusing and growing analytical caring minds to become better problem solvers. Visual learning tools provide an opportunity for leveraging the more natural visual acuity of learners towards greater conceptual understanding, knowledge, and appreciation of complex but common real world events. Visual tools involve picturing ways for presenting various 'for instances' and 'what if' scenarios of real world happenings from which learners gain opportunities for practicing problem solving methods, building their own knowledge bases, and discovering Aha experiences that make science more enjoyable. Usage of contextual referent-image systems (CRS) when designing visual learning tools seems to result in more opportunities for successful problem solving learning experiences. CRS-like dosage schemes of visual imagery matched to the abilities of diverse learner groups may become more prominent as powerful curricula designer tools of activity-based educational programs for learning science and other disciplines in the third millennium.

Works such as this research study may, in the near future, invoke an era of dynamic orbital mechanical modeling in learner research studies. Such activity would likely involve the conception of learning dynamics and behaviors in terms of orbital mechanics and the development of research designer modeling tools that function in ways similar to those identified for interactions in atomic and molecular systems. These models which are akin to Galaxies of the Mind (GOM) could provide researchers with more vivid and dynamic tools for learner studies that assist, support, nurture, and analyze the learning process. Particle beams might be thought of as information streams; particle-surface bombardment as rapid information delivery systems; plasma electron energy profiles as cognitive learner

profiles; plasma fusion as thought fusion. Fingerprinting learner groups and learning systems, characterizing learners by the fine line splitting of energy learning states, and visualizing learner movement between energy states are suggestive of alternative ways for studying diverse learning communities exposed to advanced, flexible, boundless, complex, and rapid information delivery systems.

New capabilities and miniaturization of technologies are ushering in a new renaissance for ways of thinking about the world, studying the forces under which it functions, and exploring possible paths for journeys into the future and the ever evolving state of the mind of the learner. Changing technology capabilities seem to move learner experiences toward success in more effortless ways that inspire and motivate learners filled with excitement and enthusiasm. Ways are needed for knowing whether learner responsiveness to difficulties results in recognition and acceptance of challenges along the path of adventure toward success or some mindless expression resulting from unexercised capabilities for operating in the challenge zones.

Learning means striving in some conscious way to make sense of something, to make something more understandable, more intelligible to self and others in ways that empowers learners to interact, think, and problem solve as difficulties and challenges arise from ones environment. Learning needs to occur in a way that allows learners to be more in control of their own learning processes, procedures, and events in a way that empowers learners to expand knowledge bases and build new ones to work with the challenges in their environment. Stakeholders in the learning process, teachers and students, all need something to set their sites and from which to gauge their progress; they need clearly identified and defined goals for learner success and maps suggestive of pathways to those goals. Learning can be fun and enjoyable but requires commitment of time, energy, and effort through active participation in the process to gain fruitful learning experiences. Learners need ways for becoming better equipped with tools for learning as well as places and opportunities for learning better. Learners need more tools that help them think about

things, processes, events, and happenings in new and more creative ways never before dreamed if today's learners are to develop capabilities for building new worlds for tomorrow.

## Recommendations

The research findings for this study are grouped into four categories suggestive of REAL science tech-models for growing analytical caring minds (ACM):

(a) Cluster A: visual tools for inspiring analysis,

(b) Cluster B: identifying with diverse learner groups,

(c) Cluster C: visual tools for improving attitudes,

(d) Cluster D: nurturing a progression of learners toward success.

Hopefully, this work will suggest pathways for others to develop and implement similar tech-models in their research studies as well as be an inspiration for their efforts.

The following list identifies recommendations for directions of future research studies addressing issues for better ways of learning in a technology supported environment and living and working in a technology oriented world. Studies suggested by these recommendations focus on leveraging context-based imagery in ways that would more readily assist the learner in concept development and problem solving, using a process of recognizing and extracting information from imagery. The recommendations seek ways for identifying with diverse learner groups that are more likely to encourage and promote learner readiness in science and mathematics. The recommendations seek to encourage ways for more directly involving learners in measurement, computation, and analysis processes. They suggest a need for finding ways to assist learners in developing a sense of accountability, ownership, and confidence for analytical involvement; providing opportunities for learner immersion in creative activities using tools that stimulate learner estimation, prediction, and invention. And these recommendations suggest a need to identify community-based expert response behaviors, patterns, and systems when studying learner performance in specific content areas. These recommendations encourage studies

utilizing local expert response systems for focusing learner performance toward more appropriate expert response stimuli as well as for more accurately measuring learner progress and degree of success.

1. Studies are needed for identifying appropriate sources for the MER response, that of a more expert-like response, in the various content areas of an instructional program.

2. A MER response needs to originate from the community of learners under study and tracking MER should parallel the progress and outcomes of learners in specific instructional programs.

3. Studies are needed to understand how expert goals can serve as learner targets helping to shape learner progress and success; how expert goals function as targets for raising achievement levels and increasing opportunities for learner success.

4. Studies are needed for identifying ways learner expectations shape and drive learner achievement and ways for improving learner expectations in specific content areas to become more favorable or in line with a more acceptable and expert-like response.

5. Studies are encouraged that monitor process skill development and improved comprehension of concept-focused learning activities using varied context-based materials.

6. Studies are encouraged that identify strategies for measuring and tracking varying levels of learner effort and ways in which learner effort might correlate with the degree of learner involvement and learner expectations.

7. Studies are needed on understanding learner stimuli that influence the character and nature of problem solving in the content area, especially science and mathematics, and ways in which the functional ability to solve problems is valued in the curricula

8. Studies are needed for identifying active thinking technologies for advancing learner achievement through responsible involvement with rapid information delivery systems as opposed to surface usage of information transfer technologies which tend to disguise learner comfort and mindless activities with the need for learner effort and mindful activities engaging learners in responsible processing of learning tasks.

9. Studies should be designed that identify ways to leverage varying types of technology as stimuli for increased learner motivation, enthusiasm, excitement and enjoyment when exploring and learning about new material and building useful knowledge bases.

10. Design instruments that are precision tuned to learner behaviors, expectations and perceptions of needs for learning in the content areas from science and mathematics, to social studies, to literature, and fine arts.

11. Explore usage of new tools and ways for extracting information from visuals, both static and dynamic, to encourage improved, efficient learner comprehension of concepts.

12. Studies are needed on learner response to stimuli produced by varying multi-media styles with integrated visuals and text for focusing viewer's attention on problem recognition, altering points of view, and extracting information relevant to image analysis and problem solving.

13. Identify, design, implement activities utilizing miniature analytical devices and systems at the forefront of revolutionary changes being made in science and medical fields of instrumentation.

14. Identify ways disciplines differing in content and goals might complement and leverage one another for improving learner responsiveness and problem solving behaviors.

15. Examine learner cognitive profiles for aptitude, attitude, achievement and ability that shape learner belief-knowledge patterns towards a more expert-like response (MER).

16. Explore usage of context-based imagery to facilitate learning objectives and provide more flexibility to learner perspectives through altered frames of reference, points of view.

17. Explore learner recognition and usage of relevant and significant information versus what is unimportant as a function of varied supporting visuals when solving problems.

18. Encourage guidance to work more closely with teachers in the formative instructional program of learners and in helping teachers to stay abreast of interdisciplinary signs of learner performance shifts with implications for the instructional program.

19. Change school focus and expectations from one of sports and athletic fame to one of academic excellence; encourage and expect success in content subject areas.

20. Study learner usage of analytical tools and types of experiences that promote learner behavior using such tools as tables, graphs, labeled pictures for extracting information and further inquiry

21. Study ways to infuse learner perceptions with the understanding that amount of effort extended is a dominant factor that determines how successful or expert-like a learner becomes in some content area

22. Further investigations are needed into the meaning and significance of the non-response alternative which identify the implications of non-responsiveness on instruction and explore ways to more efficiently track and account for non-response and response variants to assessments.

23. Recognize that learning processes in science require engagements that involve allocation of time, space, and resources for investigating activities and that trial and error is a vital portion of learning and development of problem solving skills.

24. Conduct more research on problem solving experiences for learners and how learner ability evolves across a spectrum of learners towards greater maturity and success.

25. Study impact of technology resources on accelerated learning experiences such as what this might mean in terms of learner readiness and work preparedness as well as expectations in the workplace.

26. Explore activities that interface learners with sophisticated visual planning tools such as ground and satellite map imagery, modeling complex physical systems, engaging simulation dynamics of various modeling systems.

27. Explore on-line capabilities for learning any time and any place using rapid and flexible information delivery systems.

28. Provide more opportunities for young learners in secondary school to have experiences about physics.

29. Deliver the message that all learners are invited and expected to join the experts and provide more expert-like responses on their journey to success and that all learners are on a mission to become expert-like in response to specific areas of endeavor.
30. Compile inventory of learner perspectives toward learning; design and implement expectation instruments addressing issues relative to specific content areas and learning opportunities as well as difficulties in that area or discipline.
31. Find alternative ways for communicating concepts using visual tools, both dynamic and static, which make use of interactive multi-media in hard copy and electronic forms of text and graphic displays.
32. Study outcomes from assessing in the same medium in which the learner learns as opposed to assessing in more traditional mediums; study variations in learner comprehension of concepts as a function of assessment medium.
33. Identify with traits, behaviors, characteristics, expectations of diverse learner groups and use research tools for finding ways to amplify success opportunities for specific learner groups.
34. Study more ways to provide learners with varied perspectives, points of view, frames of reference and matching and selecting preferred tools for different kinds of analysis and usage of an assortment of visual tools for exercising different analytical abilities.

## A Final Perspective

A final perspective on fruitful thought from this investigator is connected with a discussion with her father when he commented "we become old to grow young again". This statement captures the essence of evolving thought. As one's mind matures in wisdom with age, one's own thoughts become older, seem more used, show wear--often from overuse. But at various stages, a most amazing thing happens. Older thoughts seem to be transformed into newer, younger ones--oftentimes showing no resemblance to the older ones. And in a very real sense, one grows young as one becomes older through a well-born of newfangled thoughts and ideas. Ones thoughts escape a ripple in the space-

time continuum moving through regions of discontinuity into new realms of enlightened thought and innovative ideas. Hence, inquiry invokes interest, which begets inspiration. Inspiration begets innovation, intuition, and ingenuity. And, ingenuity begets invention. Thus the real value of thought can be discovered through inquiry. And thought valued for its own essence provides visions of possibilities for how fruitful it might become with the passage of time!

# APPENDIX A
# CLASSROOMS IN TRANSITIONS

## Instructional Technology in the Nineties

- Overview of the Problem in the Classroom
  - Some Costs Drop - Others Increase
  - Speed, Access, Ease of Use Increase
  - Web-based Information Delivery Systems Arrive
  - Many Computing Activities Involve Low Quality Time
  - Web Distracters Compete with Instruction
    - Playing Games, Browsing, Keyboarding
  - Effective Classroom Web Interface Missing

Figure A-1. Instructional Technology in the Nineties.

## Need for Classroom Technology Models

- Rapidly Changing Classroom Landscapes
- Diverse Populations Using New Tools
- Learner Success Prompts Need for:
  - Effective Student Grouping
  - Monitoring Learner Progress
  - Designing New Assessment Strategies
  - Use of Research Modeling Tools
  - Designing New Learning Tools

Figure A-2. Need for Classroom Technology Models.

## Classroom Solutions : Tech Tools

- Transparent, High Speed Network
- Centralized Web-Based Assessment
- Technology Assisted Learning
- 3-D Visualization Tools
- Innovative Web Tools
  - Forums, Web Cams,
  - Videoconferencing
  - GPS and GIS Tools

Figure A-3. Classroom Solutions: Tech Tools.

## Applications of the Model In Technology Supported Environments

- Web-Based Delivery Instruction
  - CyberScience, CyberPhysics, CyberChemistry
  - Tools for Assessment Strategies
  - Learner cognitive profiles: Attitude, Aptitude, Achievement
- Transportable to Classroom Settings

Figure A-4. Applications of the Model in Technology Supported Environments.

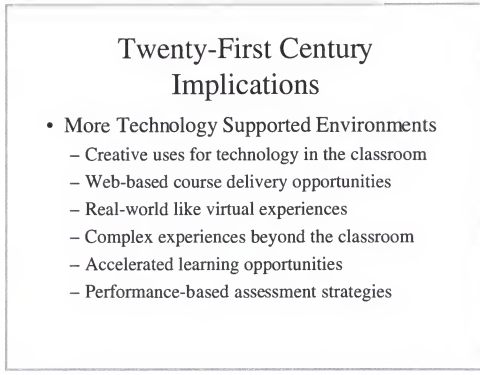

Twenty-First Century Implications
• More Technology Supported Environments
– Creative uses for technology in the classroom
– Web-based course delivery opportunities
– Real-world like virtual experiences
– Complex experiences beyond the classroom
– Accelerated learning opportunities
– Performance-based assessment strategies

Figure A-5. Twenty-First Century Implications.

# APPENDIX B
# MODELING FOR LEARNER SUCCESS

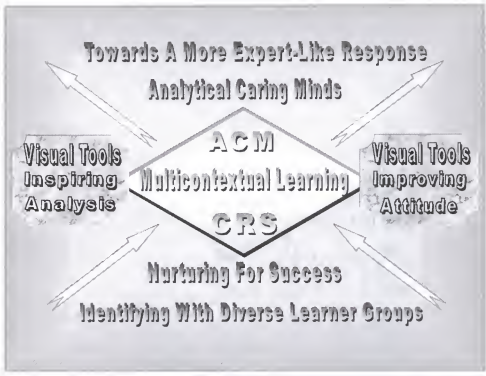



Figure B-1. Towards A More Expert-Like Response.

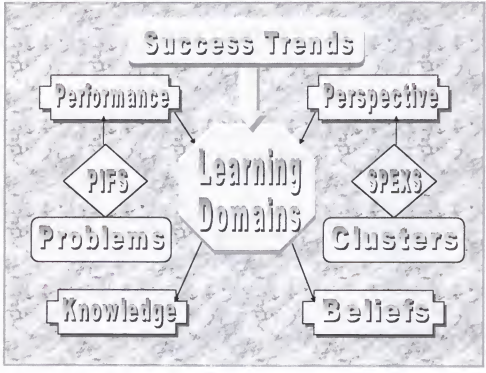



Figure B-2. Success Trends for Performance and Perspectives.

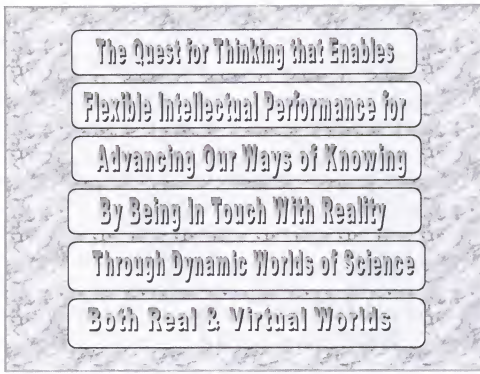

The Quest for Thinking that Enables
Flexible Intellectual Performance for
Advancing Our Ways of Knowing
By Being In Touch With Reality
Through Dynamic Worlds of Science
Both Real & Virtual Worlds

Figure B-3. The Quest for Thinking.

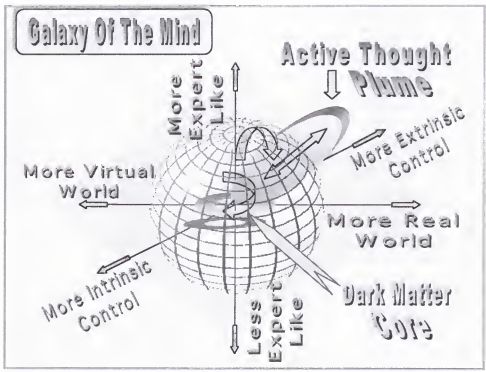
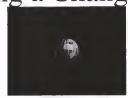



Figure B-4. Galaxy of the Mind (GOM).

## Envisioning a Changing World



- Merging of Real and Virtual Worlds
  - Through Sound, Touch, & Visual Immersion
  - Using Contextual-Imagery Referent Systems
  - In Technology Supported Environments
  - Filled with Rich Contextual Analogues
  - That Nurture Analytical Caring Minds and
  - Prompt Dynamic Conceptual Development
  - Using Active Galaxies of the Mind

Figure B-5. Envisioning a Changing World.

## REAL Science Tech-Models

- Making Sense of Problem Solving
  - Picture a Context-Rich Problem
  - Ask Questions from the Picture
  - Extract Data from the Picture
  - Analyze the Data and Visualize
  - Compare Analysis to the Picture
  - Draw Conclusions From the Data
- Spatial and Temporal Solutions

Figure B-6. REAL Science Tech-Models.

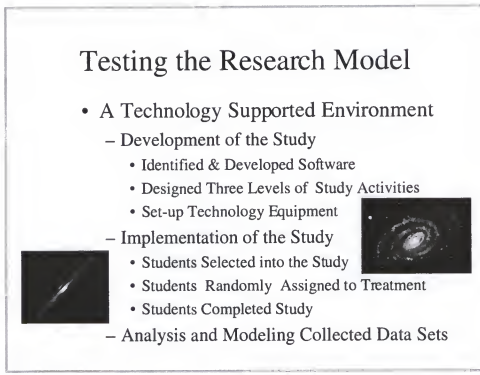

Testing the Research Model
• A Technology Supported Environment
– Development of the Study
• Identified & Developed Software
• Designed Three Levels of Study Activities
• Set-up Technology Equipment
– Implementation of the Study
• Students Selected into the Study
• Students Randomly Assigned to Treatment
• Students Completed Study
– Analysis and Modeling Collected Data Sets

Figure B-7. Testing the Research Model.

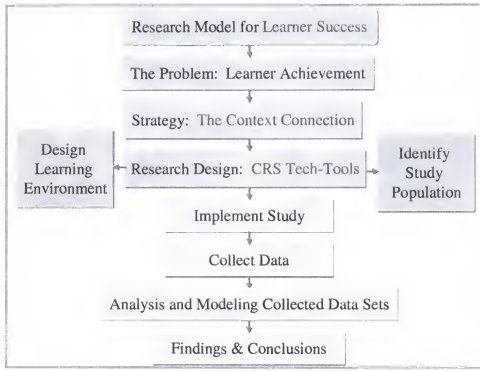



Figure B-8. Research Model for Learner Success.

# APPENDIX C
# LEARNING ENVIRONMENT

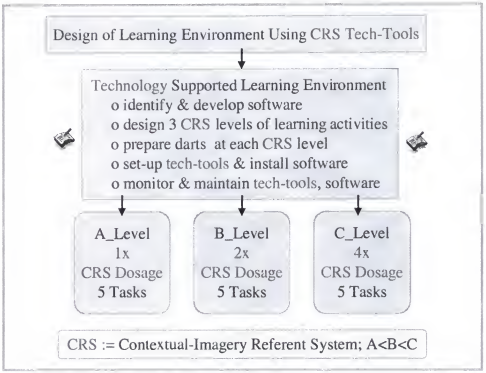



Figure C-1. Design of Learning Environment Using CRS Tech Tools.

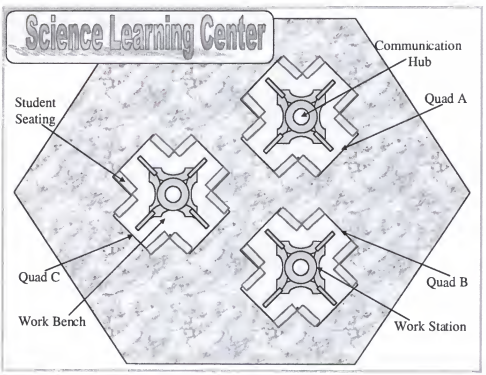



Figure C-2. Science Learning Center: Hi-Tech Quad Workstation Cluster Design.

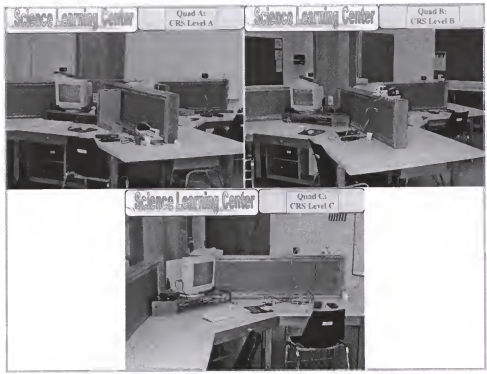



Figure C-3. Three CRS Level Learning Stations in the Science Learning Center.

Figure C-4. Science Learning Center: CRS Level A Learning Station.

Figure C-5. Science Learning Center: CRS Level B Learning Station.

Figure C-6. Science Learning Center: CRS Level C Learning Station.

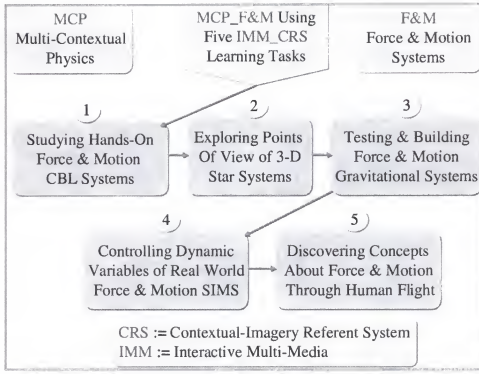



Figure C-7. Multi-Contextual Physics for Force and Motion Systems.

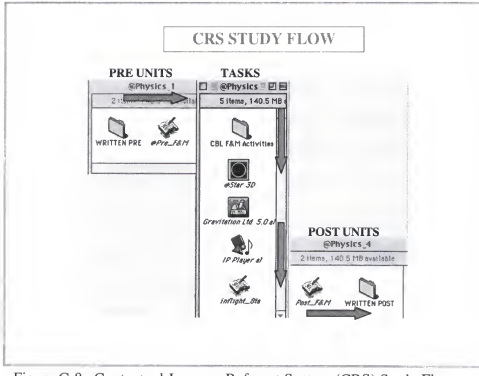



Figure C-8. Contextual-Imagery Referent System (CRS) Study Flow.

# APPENDIX D
# CRS TREATMENT: LEARNING TASKS OVERVIEW

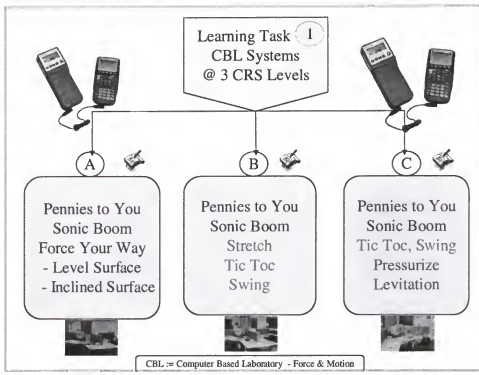



Figure D-1. Learning Task 1: CBL Systems at 3 CRS Levels.

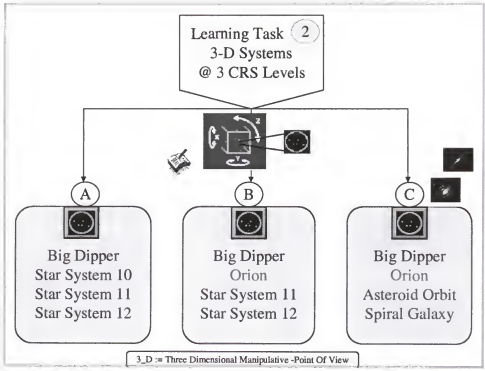



Figure D-2. Learning Task 2: 3-D Star-field Systems at 3 CRS Levels.

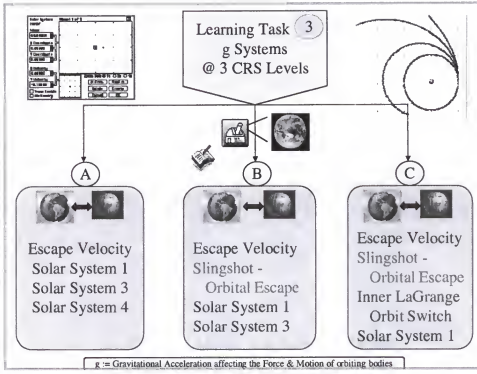



Figure D-3. Learning Task 3: g Systems at 3 CRS Levels.

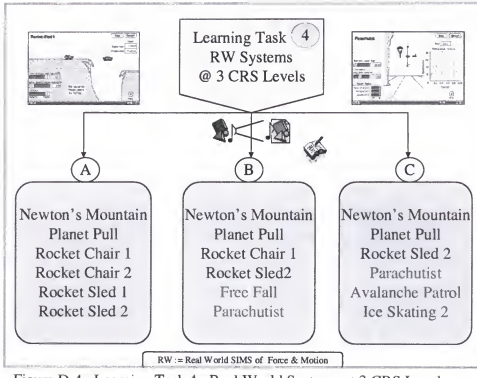



Figure D-4. Learning Task 4: Real World Systems at 3 CRS Levels.

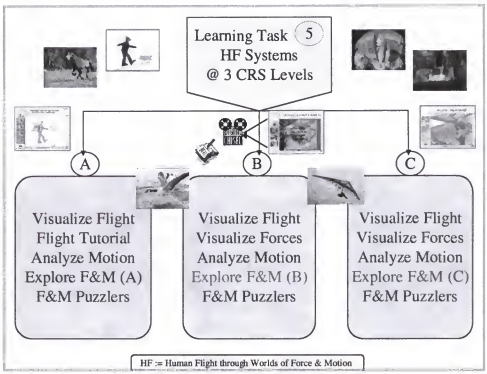



Figure D-5. Learning Task 5: Human Flight Systems at 3 CRS Levels.

APPENDIX E
CRS TREATMENT BY LEARNING TASK & CRS LEVEL

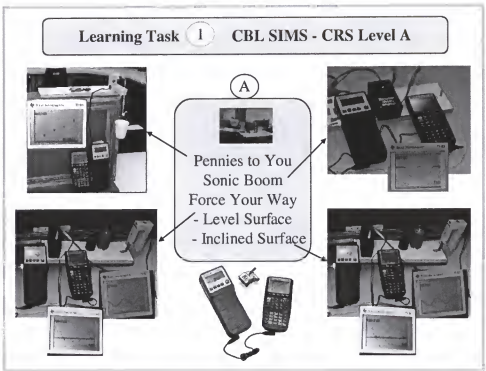



Figure E-1. Learning Task 1: CBL Systems at CRS Level A.

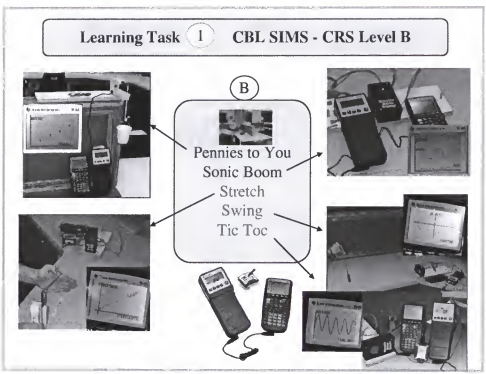



Figure E-2. Learning Task 1: CBL Systems at CRS Level B.

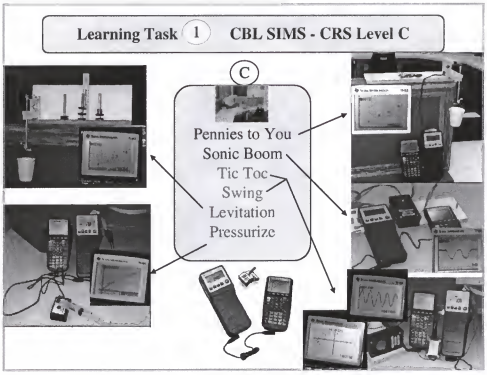



Figure E-3. Learning Task 1: CBL Simulations--CRS Level C.

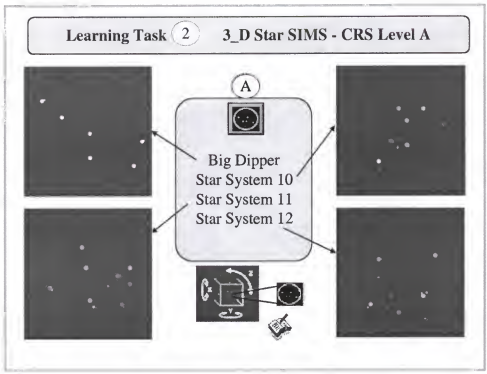



Figure E-4. Learning Task 2: 3_D Star Simulations--CRS Level A.

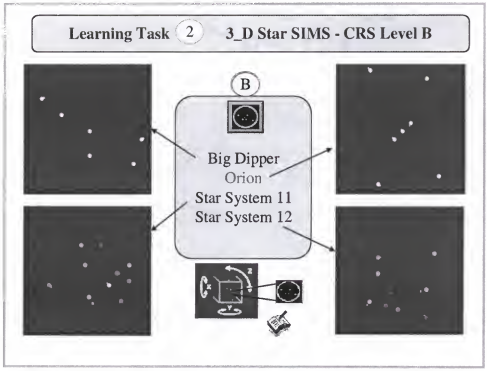



Figure E-5. Learning Task 2: 3_D Star Simulations--CRS Level B.

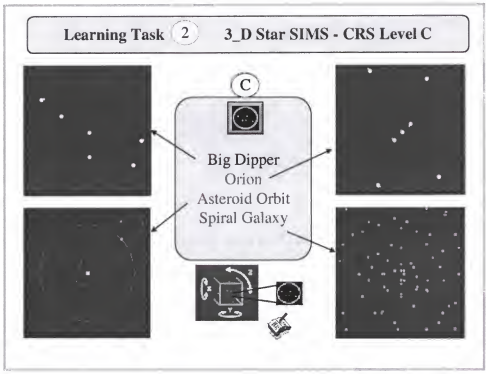



Figure E-6. Learning Task 2: 3_D Star Simulations--CRS Level C.

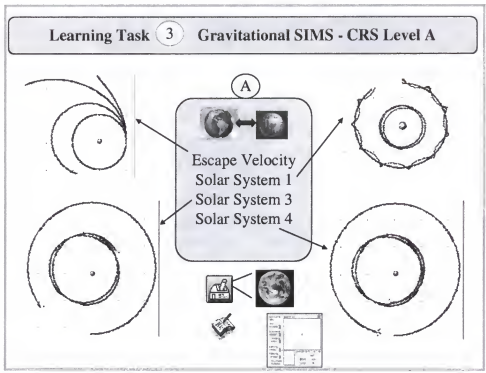



Figure E-7. Learning Task 3: Gravitational Simulations--CRS Level A.

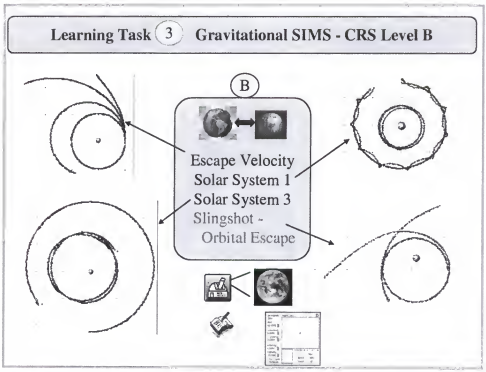



Figure E-8. Learning Task 3: Gravitational Simulations--CRS Level B.

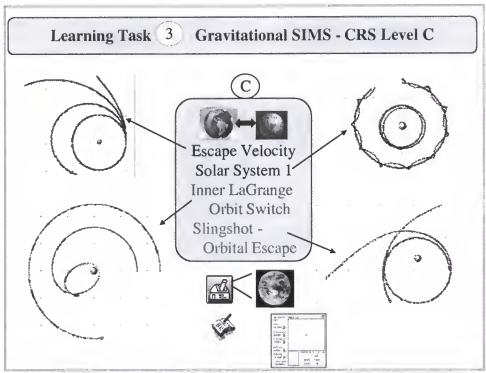



Figure E-9. Learning Task 3: Gravitational Simulations--CRS Level C.

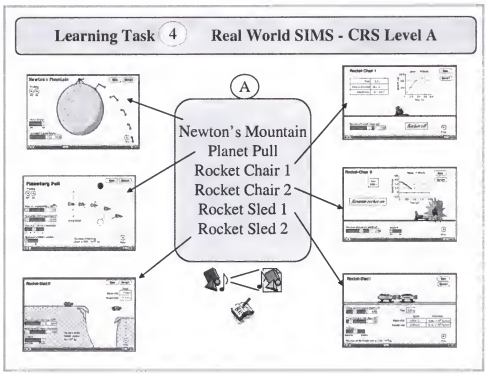



Figure E-10. Learning Task 4: Real World Simulations--CRS Level A.

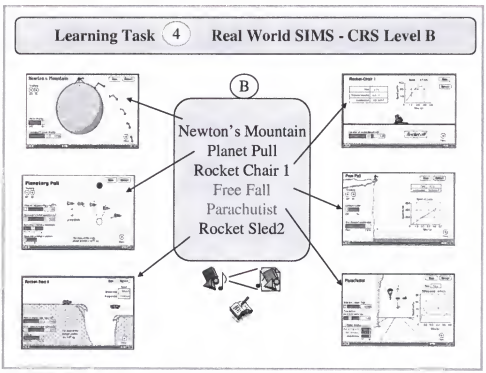



Figure E-11. Learning Task 4: Real World Simulations--CRS Level B.

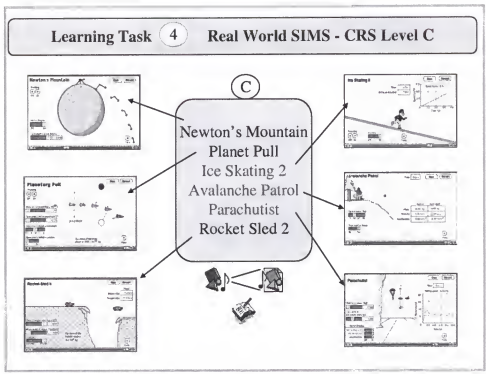



Figure E-12. Learning Task 4: Real World Simulations--CRS Level C.

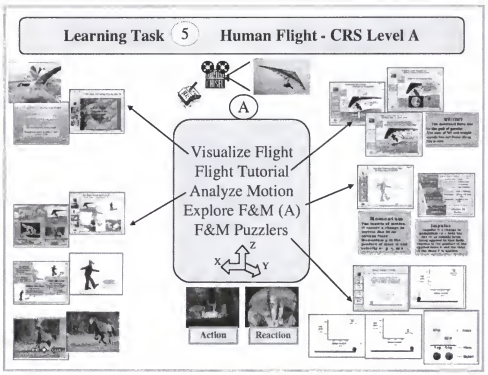



Figure E-13. Learning Task 5: Human Flight--CRS Level A.

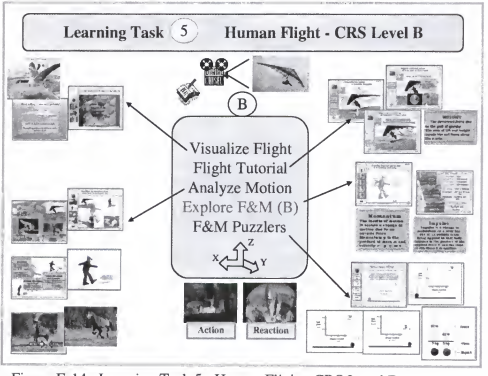



Figure E-14. Learning Task 5: Human Flight--CRS Level B.

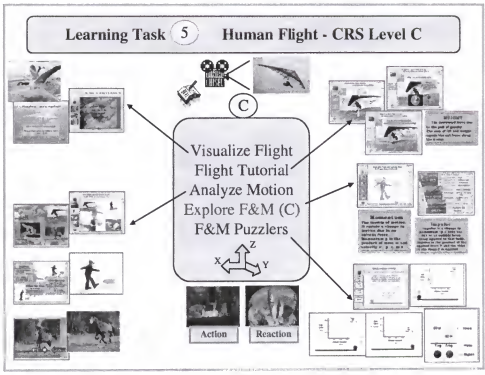



Figure E-15. Learning Task 5: Human Flight--CRS Level C.

# APPENDIX F
# IDENTIFYING STUDY POPULATION

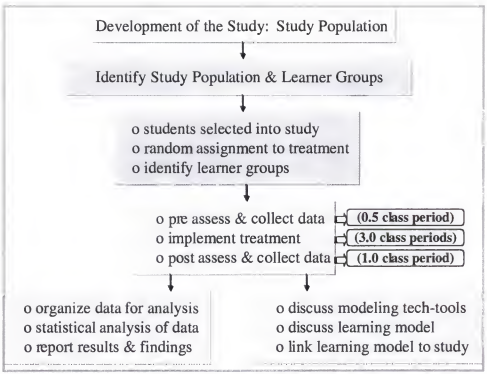

Development of the Study: Study Population
Identify Study Population & Learner Groups
o students selected into study
o random assignment to treatment
o identify learner groups
o pre assess & collect data
o implement treatment
o post assess & collect data
(0.5 class period)
(3.0 class periods)
(1.0 class period)
o organize data for analysis
o statistical analysis of data
o report results & findings
o discuss modeling tech-tools
o discuss learning model
o link learning model to study

Figure F-1. Development of the Study: Study Population.

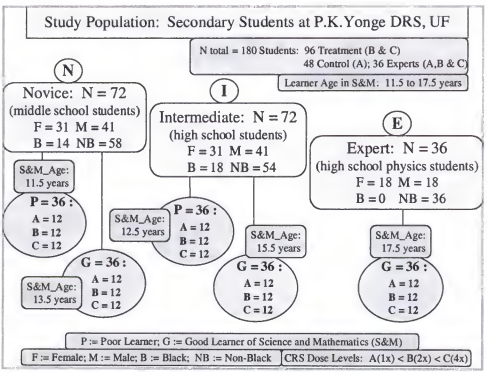

Study Population: Secondary Students at P.K.Yonge DRS, UF
N total = 180 Students: 96 Treatment (B & C)
48 Control (A); 36 Experts (A,B & C)
Learner Age in S&M: 11.5 to 17.5 years
N
Novice: N = 72
(middle school students)
F = 31 M = 41
B = 14 NB = 58
I
Intermediate: N = 72
(high school students)
F = 31 M = 41
B = 18 NB = 54
E
Expert: N = 36
(high school physics students)
F = 18 M = 18
B = 0 NB = 36
S&M_Age: 11.5 years
P = 36 : A = 12 B = 12 C = 12
S&M_Age: 12.5 years
P = 36 : A = 12 B = 12 C = 12
S&M_Age: 15.5 years
S&M_Age: 17.5 years
G = 36 : A = 12 B = 12 C = 12
S&M_Age: 13.5 years
G = 36 : A = 12 B = 12 C = 12
G = 36 : A = 12 B = 12 C = 12
P := Poor Learner; G := Good Learner of Science and Mathematics (S&M)
F := Female; M := Male; B := Black; NB := Non-Black
CRS Dose Levels: A(1x) < B(2x) < C(4x)

Figure F-2. Study Population: Secondary Students at P.K. Yonge DRS, UF.

# APPENDIX G
# DARTS FOR LEARNING ACTIVITIES

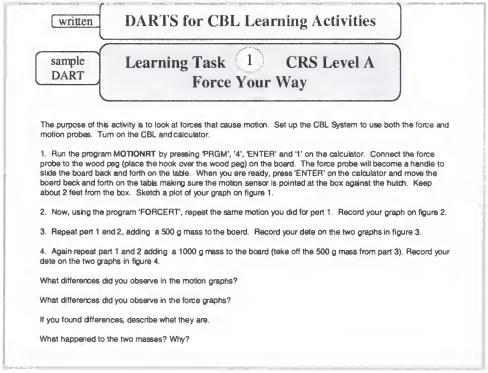

written
DARTS for CBL Learning Activities
sample DART
Learning Task 1 CRS Level A
Force Your Way
The purpose of this activity is to look at forces that cause motion. Set up the CBL System to use both the force and motion probes. Turn on the CBL and calculator.
1. Run the program MOTIONRT by pressing 'PRGM', '4', 'ENTER' and '1' on the calculator. Connect the force probe to the wood peg (place the hook over the wood peg) on the board. The force probe will become a handle to slide the board back and forth on the table. When you are ready, press 'ENTER' on the calculator and move the board back and forth on the table making sure the motion sensor is pointed at the box against the hutch. Keep about 2 feet from the box. Sketch a plot of your graph on figure 1.
2. Now, using the program 'FORCERT', repeat the same motion you did for part 1. Record your graph on figure 2.
3. Repeat part 1 and 2, adding a 500 g mass to the board. Record your data on the two graphs in figure 3.
4. Again repeat part 1 and 2 adding a 1000 g mass to the board (take off the 500 g mass from part 3). Record your data on the two graphs in figure 4.
What differences did you observe in the motion graphs?
What differences did you observe in the force graphs?
If you found differences, describe what they are.
What happened to the two masses? Why?

Figure G-1. CBL Learning Activities: Sample DART--Force Your Way.

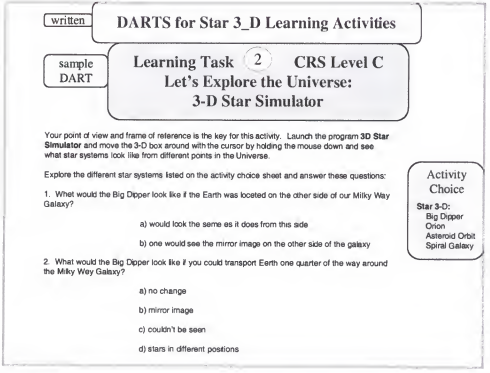
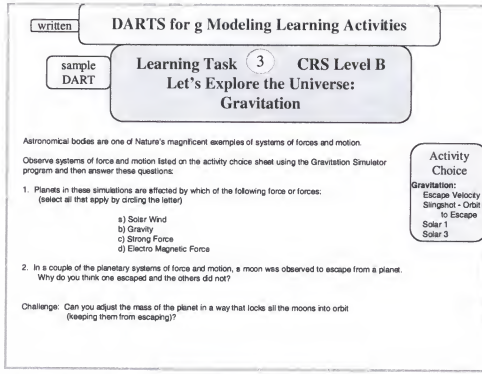

written
DARTS for Star 3_D Learning Activities
sample DART
Learning Task 2 CRS Level C
Let's Explore the Universe:
3-D Star Simulator
Your point of view and frame of reference is the key for this activity. Launch the program 3D Star Simulator and move the 3-D box around with the cursor by holding the mouse down and see what star systems look like from different points in the Universe.
Explore the different star systems listed on the activity choice sheet and answer these questions:
Activity Choice
Star 3-D:
Big Dipper
Orion
Asteroid Orbit
Spiral Galaxy
1. What would the Big Dipper look like if the Earth was located on the other side of our Milky Way Galaxy?
a) would look the same as it does from this side
b) one would see the mirror image on the other side of the galaxy
2. What would the Big Dipper look like if you could transport Earth one quarter of the way around the Milky Way Galaxy?
a) no change
b) mirror image
c) couldn't be seen
d) stars in different positions

Figure G-2. 3-D Star-Field Activities: Sample DART--Let's Explore the Universe.


written

DARTS for g Modeling Learning Activities

sample DART

Learning Task 3 CRS Level B
Let's Explore the Universe:
Gravitation

Astronomical bodies are one of Nature's magnificent exemples of systems of forces and motion.

Observe systems of force and motion listed on the activity choice sheet using the Gravitation Simulator program and then answer these questions:

1. Planets in these simulations are affected by which of the following force or forces:
(select all that apply by circling the letter)

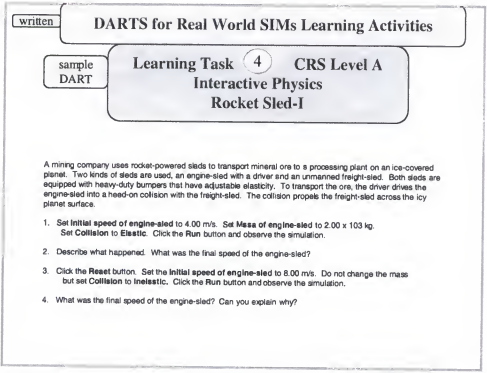
a) Solar Wind
b) Gravity
c) Strong Force
d) Electro Magnetic Force

2. In a couple of the planetary systems of force and motion, a moon was observed to escape from a planet.
Why do you think one escaped and the others did not?

Challenge: Can you adjust the mass of the planet in a way that locks all the moons into orbit
(keeping them from escaping)?

Activity Choice
Gravitation:
Escape Velocity
Slingshot - Orbit to Escape
Solar 1
Solar 3

Figure G-3. Sample DART for g Modeling Learning Activities--Written.


written

DARTS for Real World SIMs Learning Activities

sample DART

Learning Task 4 CRS Level A
Interactive Physics
Rocket Sled-I

A mining company uses rocket-powered sleds to transport mineral ore to a processing plant on an ice-covered planet. Two kinds of sleds are used, an engine-sled with a driver and an unmanned freight-sled. Both sleds are equipped with heavy-duty bumpers that have adjustable elasticity. To transport the ore, the driver drives the engine-sled into a head-on collision with the freight-sled. The collision propels the freight-sled across the icy planet surface.

1. Set **Initial speed of engine-sled** to 4.00 m/s. Set **Mass of engine-sled** to 2.00 x 103 kg.
Set **Collision** to **Elastic**. Click the **Run** button and observe the simulation.

2. Describe what happened. What was the final speed of the engine-sled?

3. Click the **Reset** button. Set the **Initial speed of engine-sled** to 8.00 m/s. Do not change the mass but set **Collision** to **Inelastic**. Click the **Run** button and observe the simulation.

4. What was the final speed of the engine-sled? Can you explain why?

Figure G-4. Sample DART for Real World Sims Learning Activities--Written.

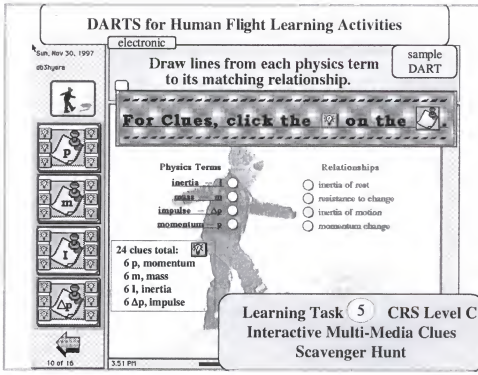



Figure G-5. Sample DART for Human Flight Learning Activities--Electronic.

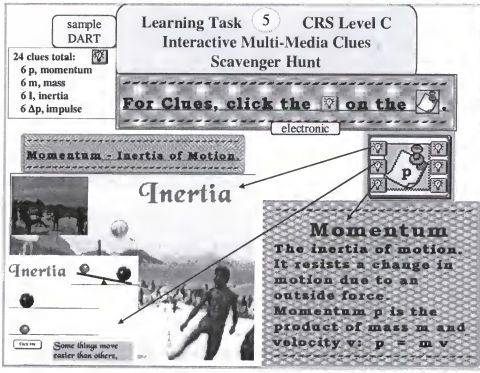

sample DART
Learning Task 5 CRS Level C
Interactive Multi-Media Clues
Scavenger Hunt
24 clues total:
6 p, momentum
6 m, mass
6 I, inertia
6 Δp, impulse
For Clues, click the on the .
electronic
Momentum - Inertia of Motion
Inertia
Inertia
Momentum
The inertia of motion. It resists a change in motion due to an outside force. Momentum p is the product of mass m and velocity v: p = m v
Some things move easier than others.

Figure G-6. Sample DART for Human Flight CRS Level C--Electronic.

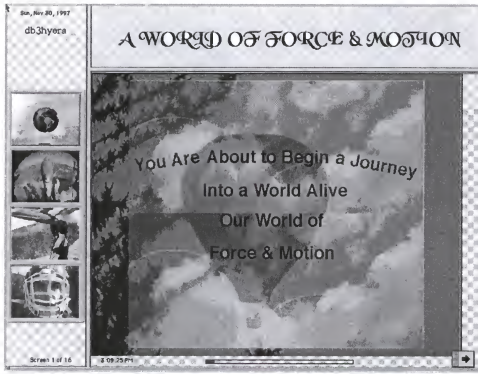

Sun, Nov 30, 1997
db3hyers
A WORLD OF FORCE & MOTION
You Are About to Begin a Journey
Into a World Alive
Our World of
Force & Motion
Screen 1 of 16

Figure G-7. Sample DART for Human Flight Learning Activities--Electronic.

Sun, Nov 30, 1997
db3hyers
Hang gliding - a dream come true!
Hang gliding requires the ability
to control motion in flight.
Screen 4 of 16

Figure G-8. Sample DART for Human Flight Learning Activities--Electronic.

Sun, Nov 30, 1997
db3hjere
Hang gliding - a dream come true!
Hang gliding requires the ability to control motion in flight.
Screen 4 of 16
3:21:00 PM

Figure G-9. Sample DART for Human Flight Learning Activities--Electronic.

Figure G-10. Sample DART for Human Flight Learning Activities--Electronic.

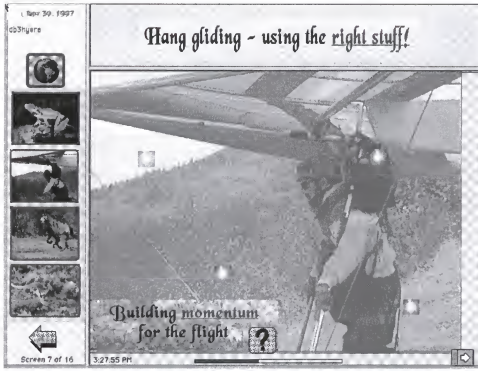



Figure G-11. Sample DART for Human Flight Learning Activities--Electronic.

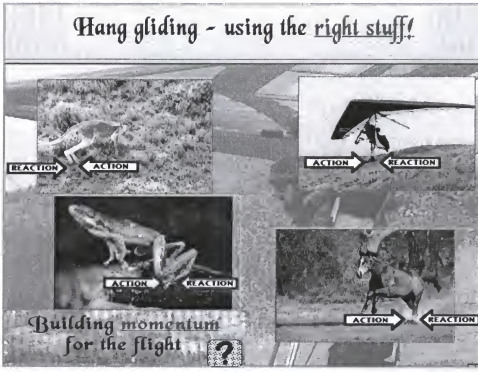



Figure G-12. Sample DART for Human Flight Learning Activities--Electronic.

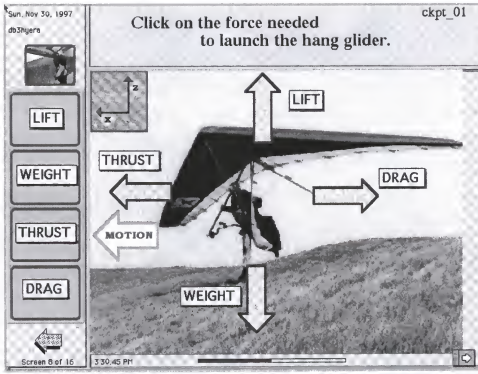



Figure G-13. Sample DART for Human Flight Learning Activities--Electronic.

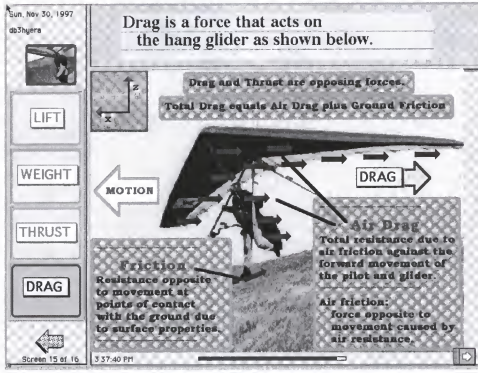

Sun, Nov 30, 1997
dbThyers
Drag is a force that acts on
the hang glider as shown below.
Drag and Thrust are opposing forces.
Total Drag equals Air Drag plus Ground Friction
LIFT
WEIGHT
THRUST
DRAG
MOTION
Air Drag
Total resistance due to air friction against the forward movement of the pilot and glider.
Air friction: force opposite to movement caused by air resistance.
Friction
Resistance opposite to movement at points of contact with the ground due to surface properties.
Screen 15 of 16
3:37:40 PM

Figure G-14. Sample DART for Human Flight Learning Activities--Electronic.

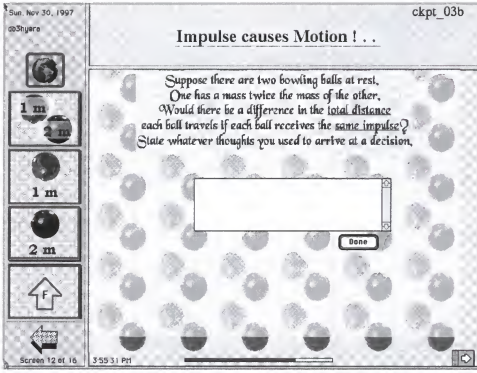

Sun Nov 30, 1997
ckpt_03b
Impulse causes Motion ! . .
Suppose there are two bowling balls at rest.
One has a mass twice the mass of the other.
Would there be a difference in the total distance
each ball travels if each ball receives the same impulse?
State whatever thoughts you used to arrive at a decision.
1 m
2 m
Done
F
Screen 12 of 16

Figure G-15. Sample DART for Human Flight Learning Activities--Electronic.

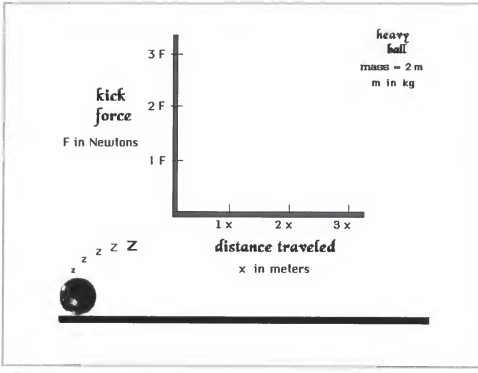



Figure G-16. Sample DART for Human Flight Learning Activities--Electronic.

# APPENDIX H
# SCIENCE & MATHEMATICS INDICATORS: MONITORING FOR SUCCESS

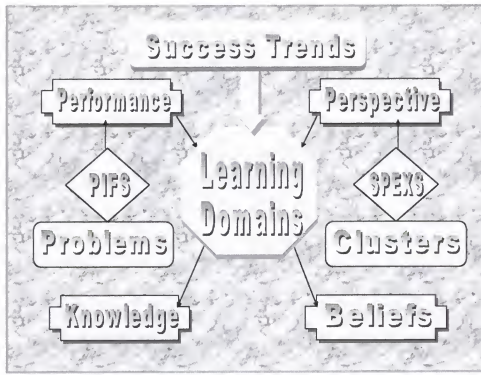



Figure H-1. Success Trends for Learner Performance and Perspectives.

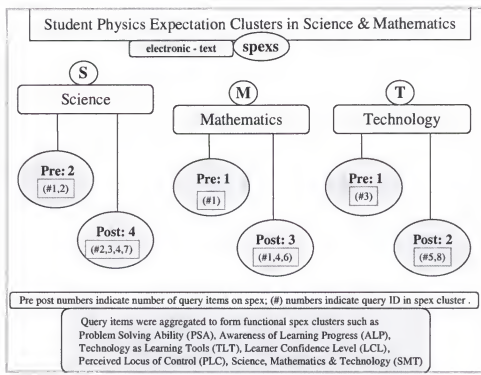



Figure H-2. Learner Expectations in Science and Mathematics--Electronic_Text.

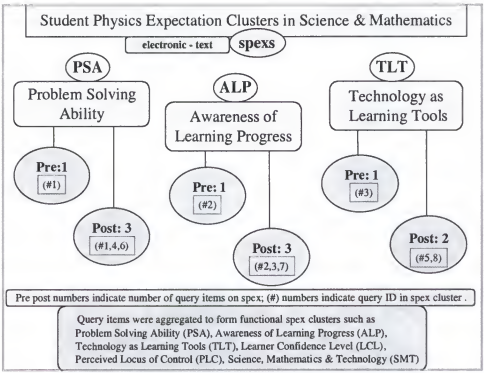



Figure H-3. Student Expectation Clusters in Science and Math--Electronic-Text.

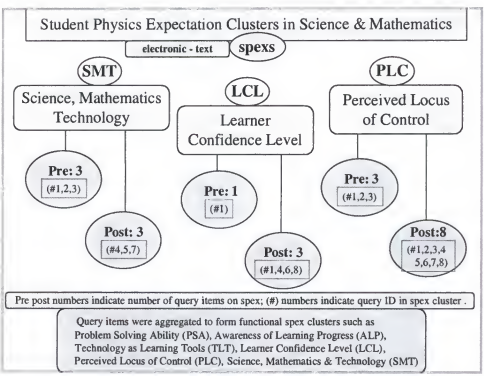



Figure H-4. Student Expectation Clusters in Science and Math--Electronic-Text.

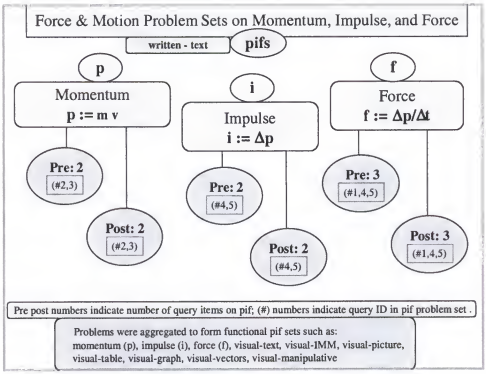



Figure H-5. Force and Motion Problem Sets--Written-Text.

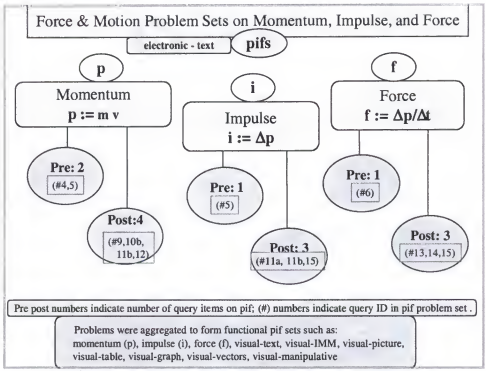



Figure H-6. Force and Motion Problem Sets--Electronic-Text.

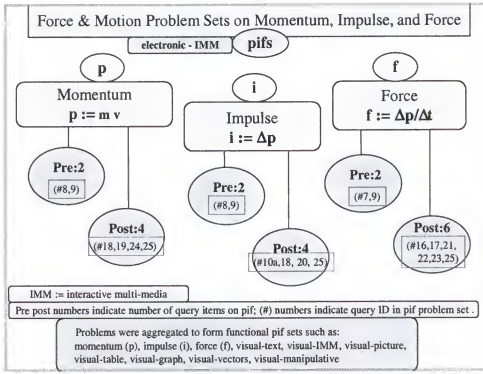



Figure H-7. Force and Motion Problem Sets--Electronic-IMM.

# APPENDIX I
# RESEARCH STUDY FACTORIAL DESIGNS

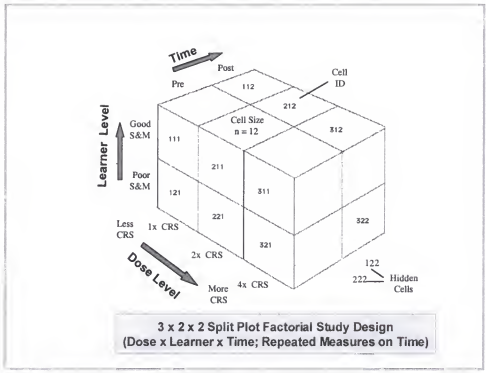



Figure I-1. Factorial Study Design: Dose x Learner (GP) x Time.

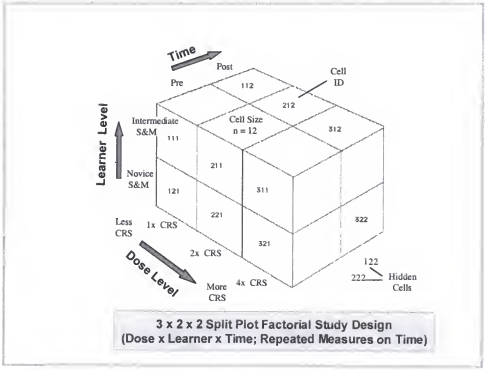



Figure I-2. Factorial Study Design: Dose x Learner (NI) x Time.

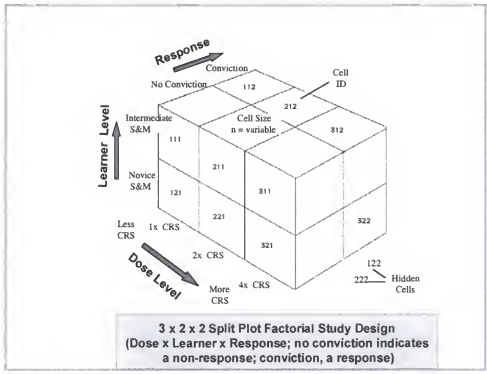



Figure I-3. Factorial Study Design: Dose x Learner_(NI) x Response.

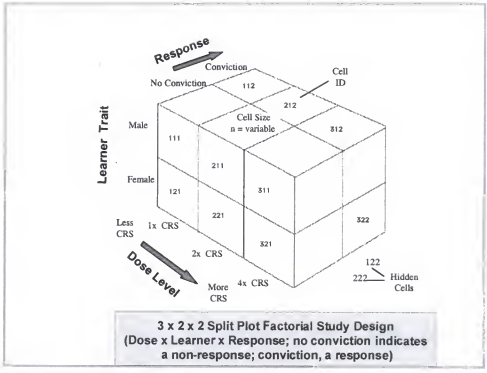



Figure I-4. Factorial Study Design: Dose x Learner_(MF) x Response.

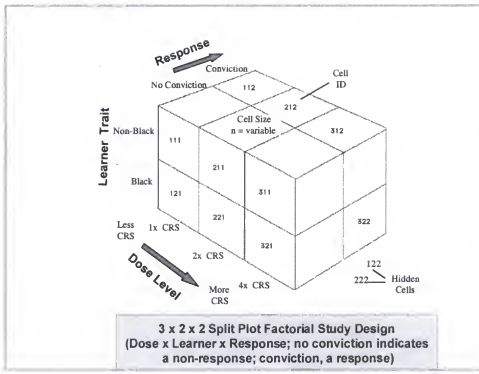



Figure I-5. Factorial Study Design: Dose x Learner_(BNB) x Response.

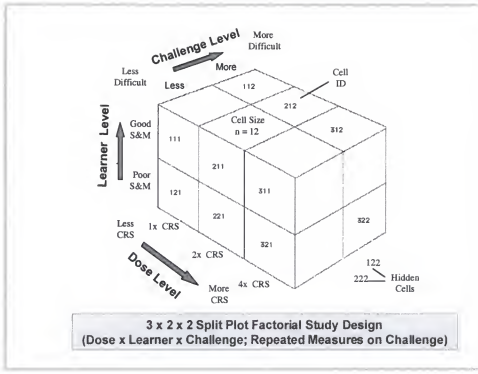



Figure I-6. Factorial Study Design: Dose x Learner_(GP) x Challenge.

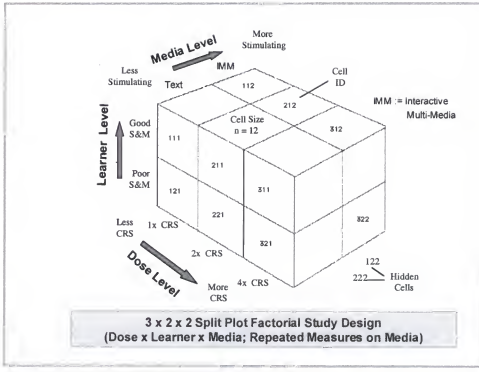



Figure I-7. Factorial Study Design: Dose x Learner_(GP) x Media.

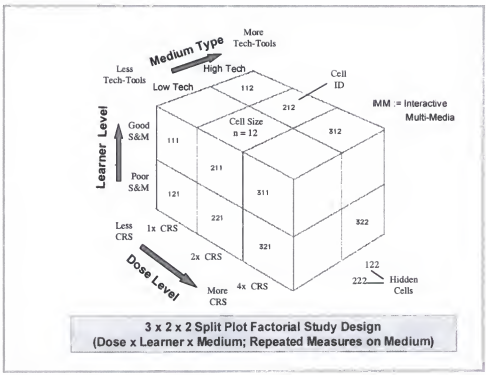



Figure I-8. Factorial Study Design: Dose x Learner_(GP) x Medium.

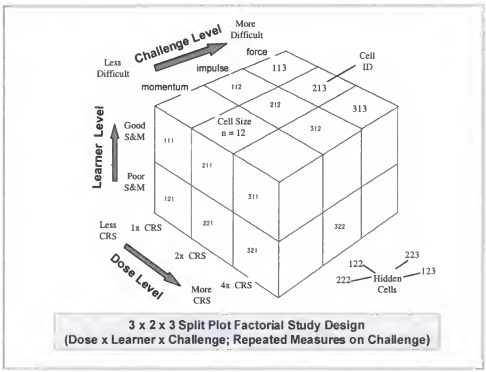



Figure I-9. Factorial Study Design: Dose x Learner_(GP) x Challenge_pif.

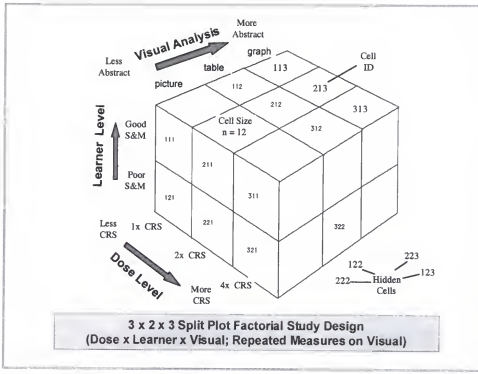



Figure I-10. Factorial Study Design: Dose x Learner_(GP) x Visual.

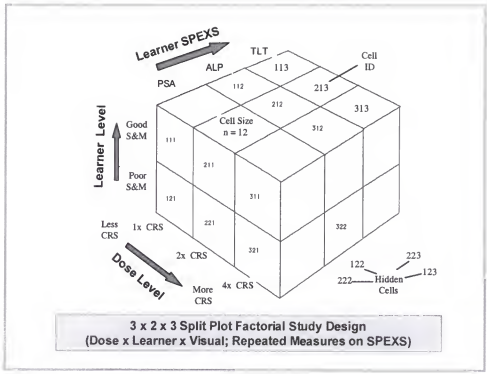



Figure I-11. Factorial Study Design: Dose x Learner_(GP) x Visual_spexs.

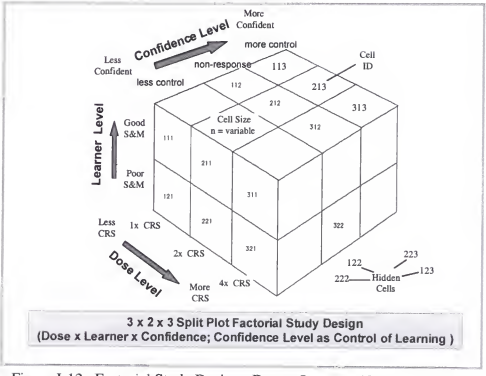



Figure I-12. Factorial Study Design: Dose x Learner_(GP) x Confidence.

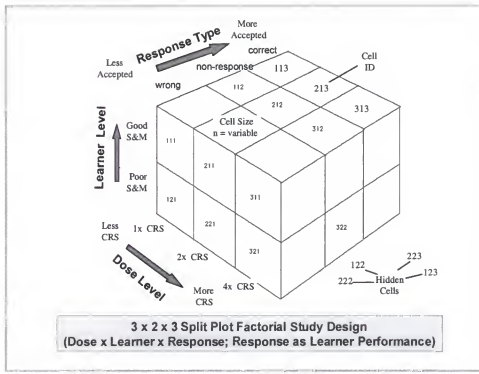



Figure I-13. Factorial Study Design: Dose x Learner_(GP) x Response.

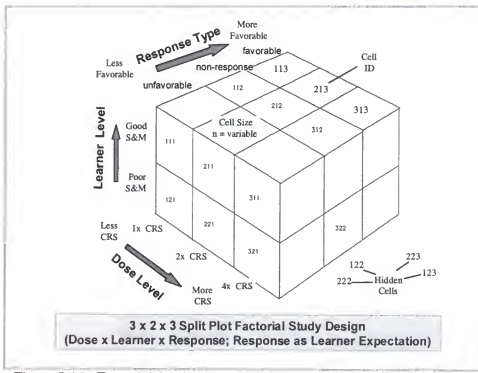



Figure I-14. Factorial Study Design: Dose x Learner_(GP) x Response.

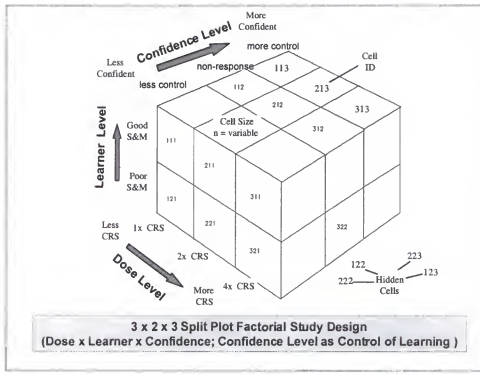



Figure I-15. Factorial Study Design: Dose x Learner_(GP) x Confidence.

# APPENDIX J
# LEARNER NON-RESPONSE CASE

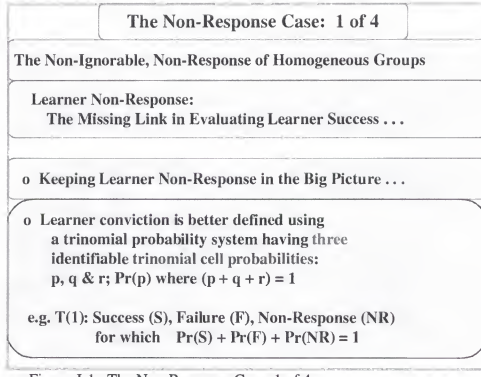

The Non-Response Case: 1 of 4
The Non-Ignorable, Non-Response of Homogeneous Groups
Learner Non-Response:
The Missing Link in Evaluating Learner Success . . .
o Keeping Learner Non-Response in the Big Picture . . .
o Learner conviction is better defined using
a trinomial probability system having three
identifiable trinomial cell probabilities:
p, q & r; Pr(p) where (p + q + r) = 1
e.g. T(1): Success (S), Failure (F), Non-Response (NR)
for which Pr(S) + Pr(F) + Pr(NR) = 1

Figure J-1. The Non-Response Case: 1 of 4.

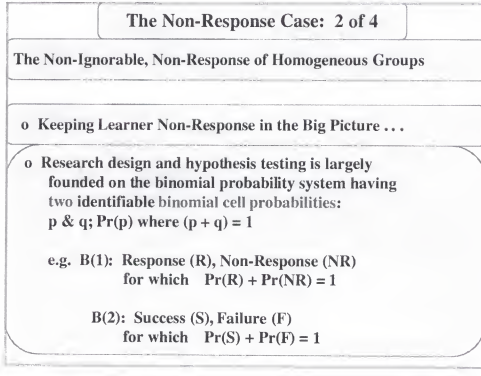

The Non-Response Case: 2 of 4
The Non-Ignorable, Non-Response of Homogeneous Groups
o Keeping Learner Non-Response in the Big Picture . . .
o Research design and hypothesis testing is largely
founded on the binomial probability system having
two identifiable binomial cell probabilities:
p & q; Pr(p) where (p + q) = 1
e.g. B(1): Response (R), Non-Response (NR)
for which Pr(R) + Pr(NR) = 1
B(2): Success (S), Failure (F)
for which Pr(S) + Pr(F) = 1

Figure J-2. The Non-Response Case: 2 of 4.

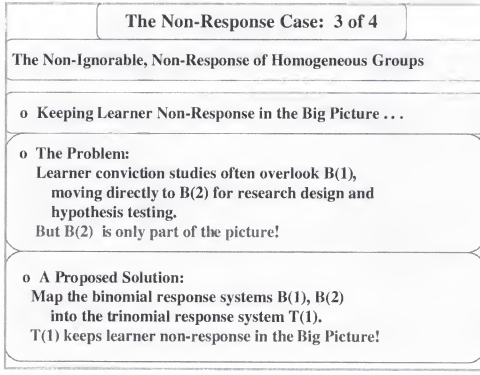

The Non-Response Case: 3 of 4
The Non-Ignorable, Non-Response of Homogeneous Groups
o Keeping Learner Non-Response in the Big Picture . . .
o The Problem:
Learner conviction studies often overlook B(1),
moving directly to B(2) for research design and
hypothesis testing.
But B(2) is only part of the picture!
o A Proposed Solution:
Map the binomial response systems B(1), B(2)
into the trinomial response system T(1).
T(1) keeps learner non-response in the Big Picture!

Figure J-3. The Non-Response Case: 3 of 4.

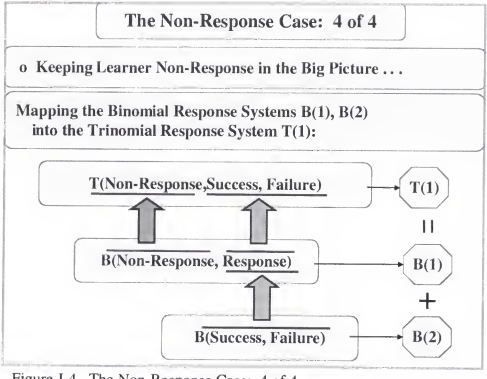



Figure J-4. The Non-Response Case: 4 of 4.

# APPENDIX K
# PRE-ASSESSMENT QUERIES

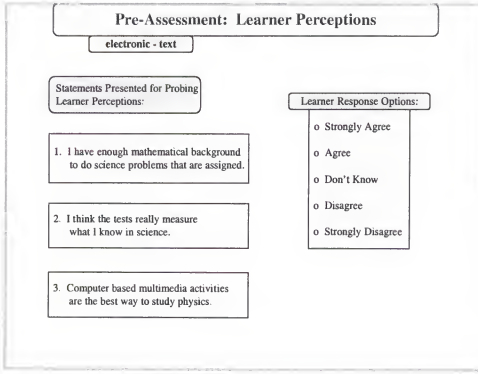

Pre-Assessment: Learner Perceptions
electronic - text
Statements Presented for Probing Learner Perceptions:
1. I have enough mathematical background to do science problems that are assigned.
2. I think the tests really measure what I know in science.
3. Computer based multimedia activities are the best way to study physics.
Learner Response Options:
o Strongly Agree
o Agree
o Don't Know
o Disagree
o Strongly Disagree

Figure K-1. Pre-Assessment: Learner Perceptions--Electronic_Text.

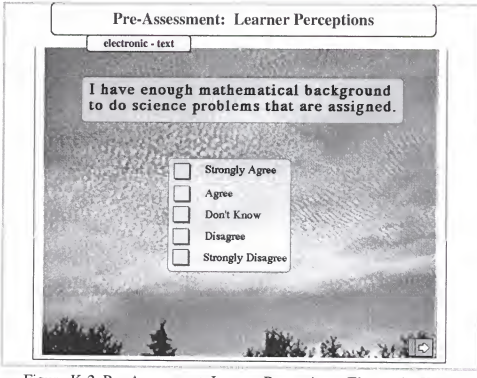



Figure K-2. Pre-Assessment: Learner Perceptions--Electronic_Text.

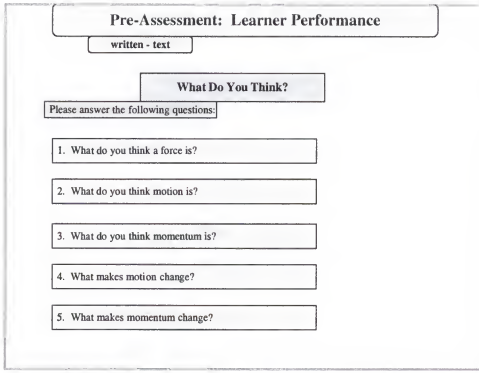

Pre-Assessment: Learner Performance
written - text
What Do You Think?
Please answer the following questions:
1. What do you think a force is?
2. What do you think motion is?
3. What do you think momentum is?
4. What makes motion change?
5. What makes momentum change?

Figure K-3. Pre-Assessment: Learner Performance--Written-Text.

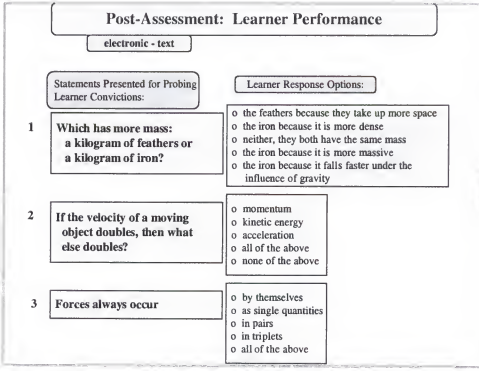

Post-Assessment: Learner Performance
electronic - text
Statements Presented for Probing Learner Convictions:
Learner Response Options:
1
Which has more mass: a kilogram of feathers or a kilogram of iron?
o the feathers because they take up more space
o the iron because it is more dense
o neither, they both have the same mass
o the iron because it is more massive
o the iron because it falls faster under the influence of gravity
2
If the velocity of a moving object doubles, then what else doubles?
o momentum
o kinetic energy
o acceleration
o all of the above
o none of the above
3
Forces always occur
o by themselves
o as single quantities
o in pairs
o in triplets
o all of the above

Figure K-4. Pre-Assessment: Learner Performance--Electronic-Text.

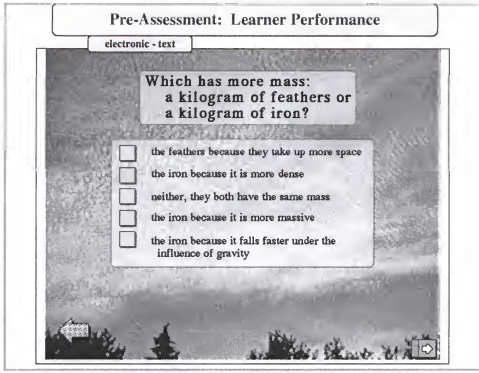

Pre-Assessment: Learner Performance
electronic - text
Which has more mass:
a kilogram of feathers or
a kilogram of iron?
the feathers because they take up more space
the iron because it is more dense
neither, they both have the same mass
the iron because it is more massive
the iron because it falls faster under the influence of gravity

Figure K-5. Pre-Assessment: Learner Performance--Electronic-Text.

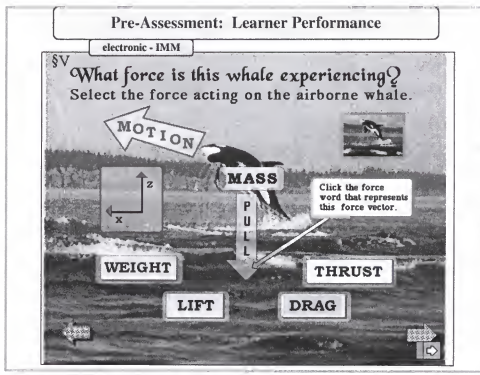



Figure K-6. Pre-Assessment: Learner Performance--Electronic-IMM.

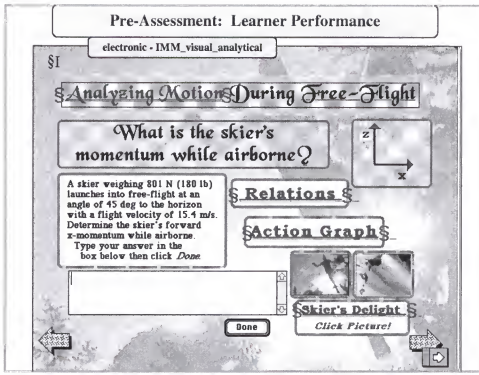

Pre-Assessment: Learner Performance
electronic - IMM_visual_analytical
§I
§Analyzing Motion§During Free-Flight
What is the skier's momentum while airborne?
z
x
A skier weighing 801 N (180 lb) launches into free-flight at an angle of 45 deg to the horizon with a flight velocity of 15.4 m/s. Determine the skier's forward x-momentum while airborne. Type your answer in the box below then click Done.
§Relations§
§Action Graph§
§Skier's Delight§
Click Picture!
Done

Figure K-7. Pre-Assessment: Performance--Electronic-IMM_Visual_Analytical.

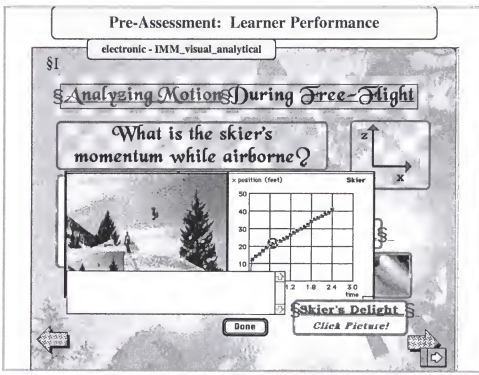



Figure K-8. Pre-Assessment: Performance--Electronic-IMM_Visual_Analytical.

# APPENDIX L
# POST-ASSESSMENT QUERIES

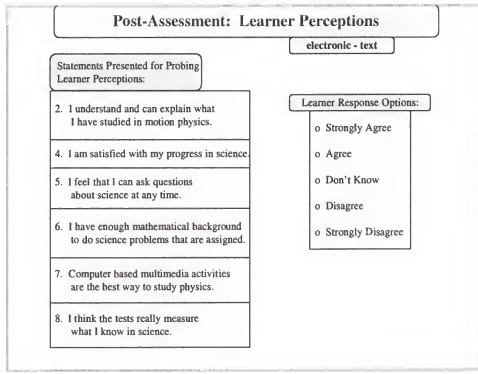

Post-Assessment: Learner Perceptions
electronic - text
Statements Presented for Probing Learner Perceptions:
2. I understand and can explain what I have studied in motion physics.
4. I am satisfied with my progress in science.
5. I feel that I can ask questions about science at any time.
6. I have enough mathematical background to do science problems that are assigned.
7. Computer based multimedia activities are the best way to study physics.
8. I think the tests really measure what I know in science.
Learner Response Options:
o Strongly Agree
o Agree
o Don't Know
o Disagree
o Strongly Disagree

Figure L-1. Post-Assessment: Learner Perceptions--Electronic_Text.

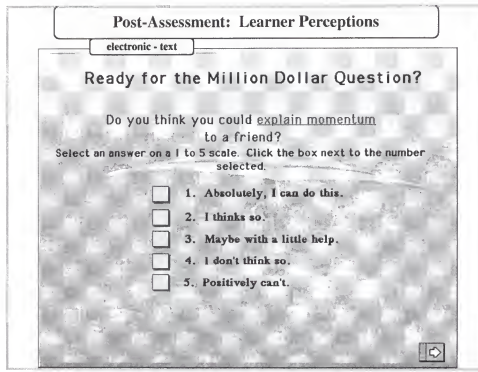

Post-Assessment: Learner Perceptions
electronic - text
Ready for the Million Dollar Question?
Do you think you could explain momentum to a friend?
Select an answer on a 1 to 5 scale. Click the box next to the number selected.
1. Absolutely, I can do this.
2. I thinks so.
3. Maybe with a little help.
4. I don't think so.
5. Positively can't.

Figure L-2. Post-Assessment: Learner Perceptions--Electronic_Text.

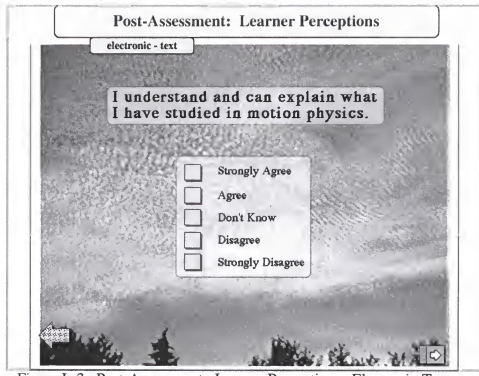



Figure L-3. Post-Assessment: Learner Perceptions--Electronic-Text.

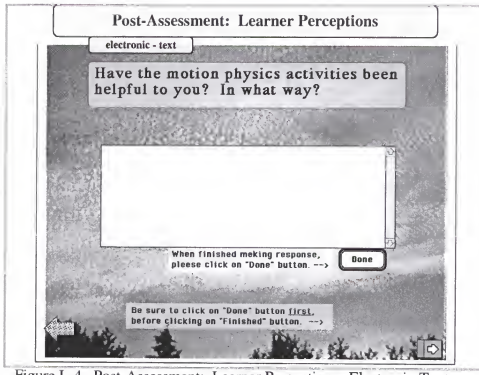

Post-Assessment: Learner Perceptions
electronic - text
Have the motion physics activities been helpful to you? In what way?
When finished making response, please click on "Done" button. -->
Done
Be sure to click on "Done" button first, before clicking on "Finished" button. -->

Figure L-4. Post-Assessment: Learner Perceptions--Electronic-Text.

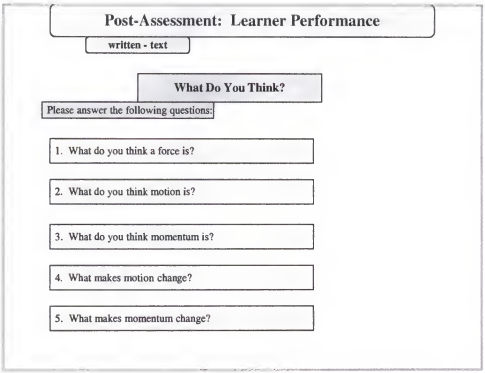

Post-Assessment: Learner Performance
written - text
What Do You Think?
Please answer the following questions:
1. What do you think a force is?
2. What do you think motion is?
3. What do you think momentum is?
4. What makes motion change?
5. What makes momentum change?

Figure L-5. Post-Assessment: Learner Performance--Written-Text.

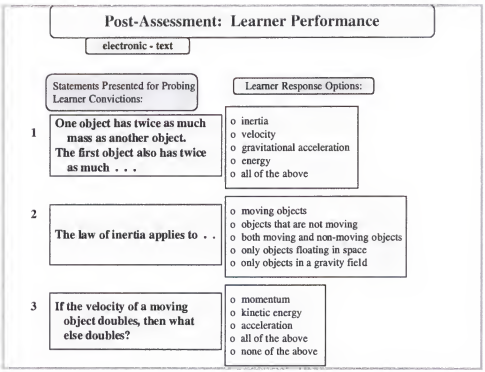

Post-Assessment: Learner Performance
electronic - text
Statements Presented for Probing Learner Convictions:
Learner Response Options:
1
One object has twice as much mass as another object. The first object also has twice as much . . .
o inertia
o velocity
o gravitational acceleration
o energy
o all of the above
2
The law of inertia applies to . .
o moving objects
o objects that are not moving
o both moving and non-moving objects
o only objects floating in space
o only objects in a gravity field
3
If the velocity of a moving object doubles, then what else doubles?
o momentum
o kinetic energy
o acceleration
o all of the above
o none of the above

Figure L-6. Post-Assessment: Learner Performance--Electronic-Text.

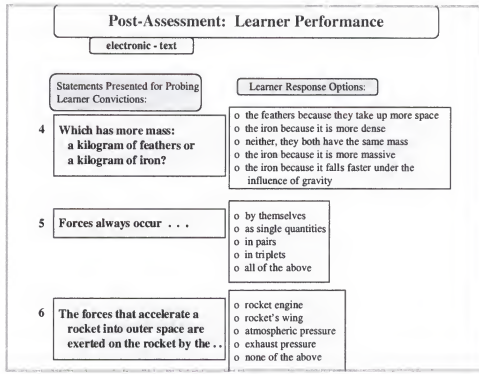

Post-Assessment: Learner Performance
electronic - text
Statements Presented for Probing Learner Convictions:
Learner Response Options:
4
Which has more mass: a kilogram of feathers or a kilogram of iron?
o the feathers because they take up more space
o the iron because it is more dense
o neither, they both have the same mass
o the iron because it is more massive
o the iron because it falls faster under the influence of gravity
5
Forces always occur . . .
o by themselves
o as single quantities
o in pairs
o in triplets
o all of the above
6
The forces that accelerate a rocket into outer space are exerted on the rocket by the . .
o rocket engine
o rocket's wing
o atmospheric pressure
o exhaust pressure
o none of the above

Figure L-7. Post-Assessment: Learner Performance--Electronic-Text.

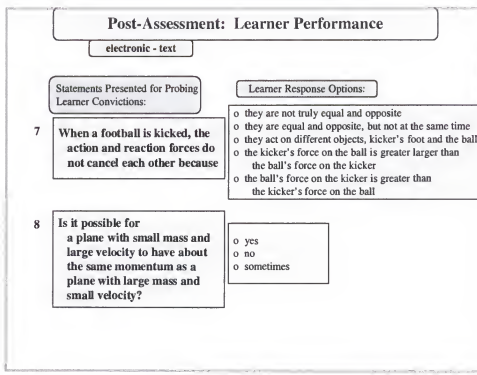

Post-Assessment: Learner Performance
electronic - text
Statements Presented for Probing Learner Convictions:
Learner Response Options:
7
When a football is kicked, the action and reaction forces do not cancel each other because
o they are not truly equal and opposite
o they are equal and opposite, but not at the same time
o they act on different objects, kicker's foot and the ball
o the kicker's force on the ball is greater larger than the ball's force on the kicker
o the ball's force on the kicker is greater than the kicker's force on the ball
8
Is it possible for a plane with small mass and large velocity to have about the same momentum as a plane with large mass and small velocity?
o yes
o no
o sometimes

Figure L-8. Post-Assessment: Learner Performance--Electronic-Text.

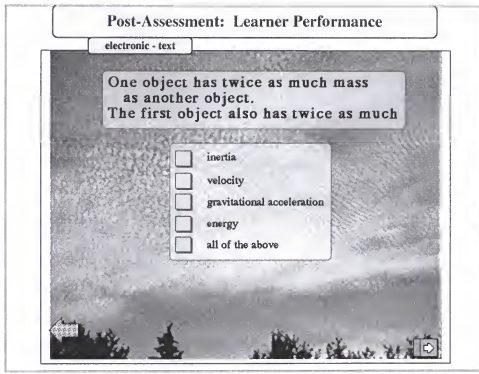

Post-Assessment: Learner Performance
electronic - text
One object has twice as much mass as another object. The first object also has twice as much
inertia
velocity
gravitational acceleration
energy
all of the above

Figure L-9. Post-Assessment: Learner Performance--Electronic-Text.

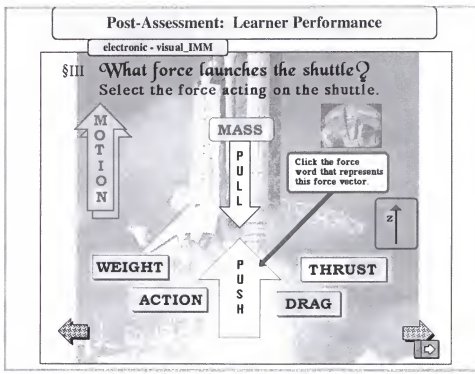



Figure L-10. Post-Assessment: Learner Performance--Electronic-Visual_IMM.

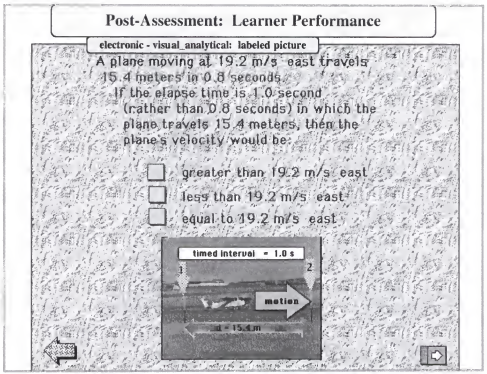

Post-Assessment: Learner Performance
electronic - visual_analytical: labeled picture
A plane moving at 19.2 m/s east travels 15.4 meters in 0.8 seconds.
If the elapse time is 1.0 second (rather than 0.8 seconds) in which the plane travels 15.4 meters, then the plane's velocity would be:
greater than 19.2 m/s east
less than 19.2 m/s east
equal to 19.2 m/s east
timed interval = 1.0 s
1
2
motion
d = 15.4 m

Figure L-11. Post-Assessment: Learner Performance--Electronic-Visual_Analytical.

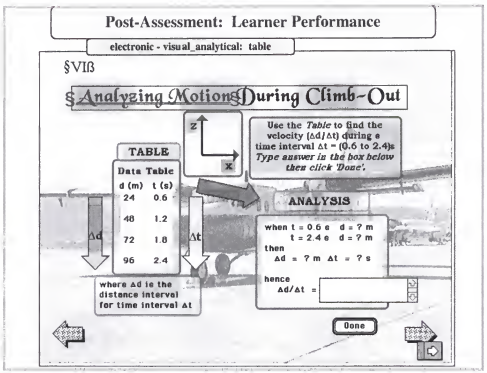



Figure L-12. Post-Assessment: Learner Performance--Electronic-Visual_Analytical.

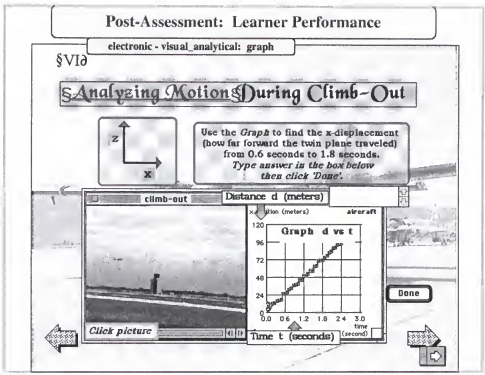



Figure L-13. Post-Assessment: Learner Performance--Electronic-Visual_Analytical.

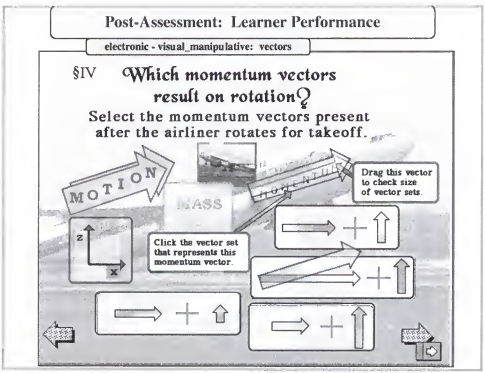

Post-Assessment: Learner Performance
electronic - visual_manipulative: vectors
§IV
Which momentum vectors result on rotation?
Select the momentum vectors present after the airliner rotates for takeoff.
MOTION
MASS
Drag this vector to check size of vector sets.
Click the vector set that represents this momentum vector.

Figure L-14. Post-Assessment: Performance--Electronic-Visual_Manipulative.

APPENDIX M
ILLUSTRATED DATA FINDINGS

## Results of the Research Study

- Study Results Indicate:
  - Learner success improves with treatment
  - Response decreases as challenge increases
  - Learner performance correlates with attitude
  - Evidence of a Non-response Presence
  - Reference is made to a progression of learners
- Non-Response Works as a Success Indicator
- Contextual Learning Promotes Thinking

Figure M-1. Results of the Research Study.

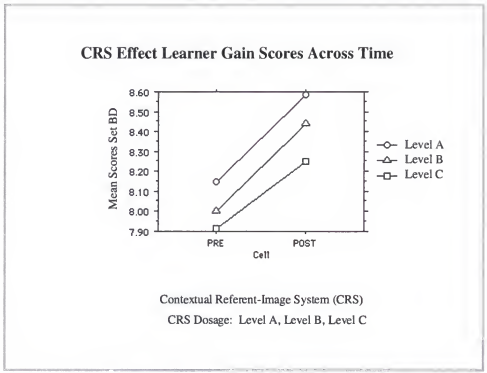



Figure M-2. CRS Effect--Learner Gain Scores Across Time.

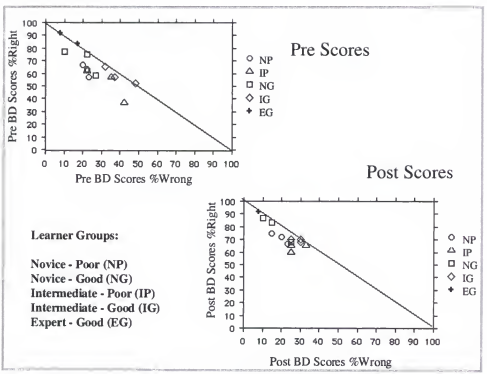



Figure M-3. CRS Effect--Learner Groups, Pre and Post Scores, Cognitive, Written.

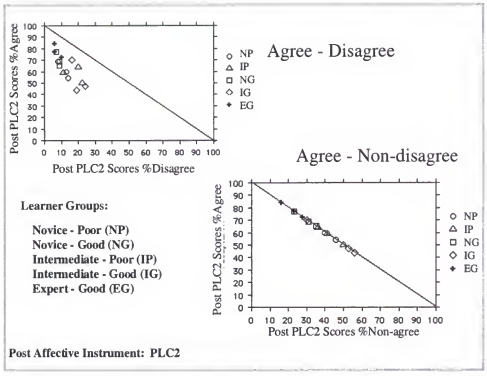



Figure M-4. CRS Effect--Learner Groups, Affective, Electronic.

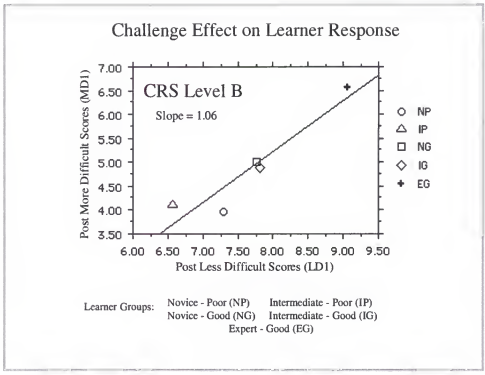



Figure M-5. Challenge Effect--Learner Groups, CRS Level B, Electronic.

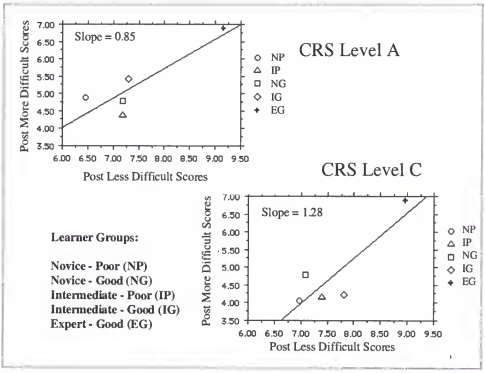



Figure M-6. Challenge Effect--Learner Groups, CRS Levels A and C, Electronic.

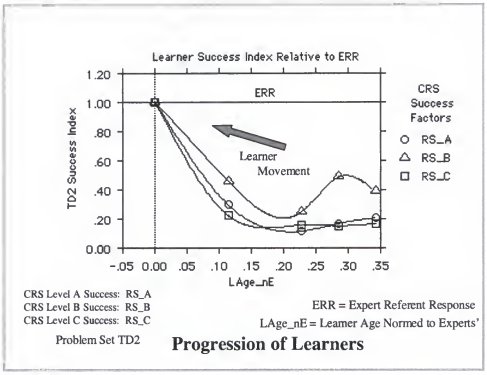



Figure M-7. Progression of Learners--Success Index x Learner Age x CRS Level.

# APPENDIX N
# LEARNER SUCCESS PARADIGMS

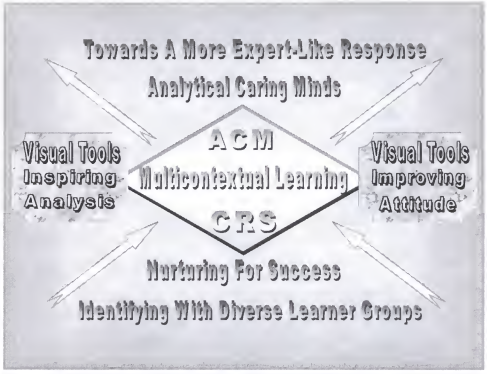



Figure N-1. Visual Tools for Multi-Contextual Learning.

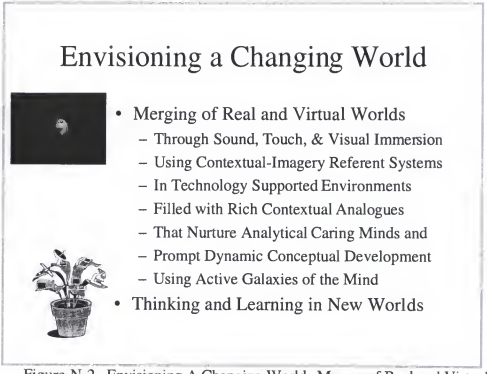

Envisioning a Changing World
• Merging of Real and Virtual Worlds
– Through Sound, Touch, & Visual Immersion
– Using Contextual-Imagery Referent Systems
– In Technology Supported Environments
– Filled with Rich Contextual Analogues
– That Nurture Analytical Caring Minds and
– Prompt Dynamic Conceptual Development
– Using Active Galaxies of the Mind
• Thinking and Learning in New Worlds

Figure N-2. Envisioning A Changing World--Merger of Real and Virtual Worlds.

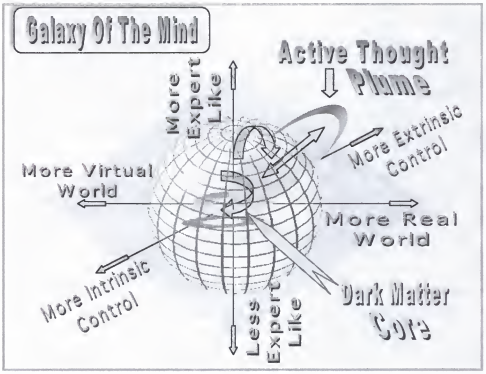



Figure N-3. Galaxy of the Mind (GOM).

# APPENDIX O
# LEARNER FEEDBACK -- WHAT DID THEY SAY?

**Learner Perception:**
**Expectations of Motion Physics by Expert, Intermediate, and Novice Learners**
Responses to query: Have the motion physics activities been helpful? In what way?

**Expert Responses at Level_A of CRS_Dose, (High School Physics Students):**

They (motion physics activities) provided a visual explanation for what happens.

Yes. They have shown us examples that help us to understand the concepts better.

These activities have not taught me anything new. They have helped a little as far as being a review activity, but I believe that they could have been better.

Now I can understand how the world works. And it is easier to predict the way things will move and react to natural occurrences.

Yes. I feel that they have helped me grasp the concepts a little more than the knowledge that I had prior to these activities.

Yes. They have helped me understand the need for motion in the universe.

They have been quite entertaining; captured my attention for a wee bit longer than bookwork. And they make me laugh sometimes.

**Expert Responses at Level_B of CRS_Dose, (High School Physics Students):**

They (motion physics activities) provided a visual explanation for what happens.

Yes. They have shown us examples that help us to understand the concepts better.

These activities have not taught me anything new. They have helped a little as far as being a review activity, but I believe that they could have been better.

Now I can understand how the world works. And it is easier to predict the way things will move and react to natural occurrences.

Yes. I feel that they have helped me grasp the concepts a little more than the knowledge that I had prior to these activities.

Yes. They have helped me understand the need for motion in the universe.

They have been quite entertaining; captured my attention for a wee bit longer than bookwork. And they make me laugh sometimes.

They are good for review. But they did not really teach me anything that I didn't already know.

Somewhat, in that this activity provided a good review. However, there was not enough time or paper available to take notes. I believe if this program were accessible, students could apply it in the areas where they felt they most needed review.

The motion physics activities have been very interesting and in a way, helpful. Computers increase your knowledge and help you to learn in a different way. We really enjoy the technology lab. Physics is phun!

No. I have not learned anything new.

**Expert Responses at Level_C of CRS_Dose, (High School Physics Students):**

The motion physics activities have been helpful because they have provided a useful hands-on learning experience to complement our book learning.

They (motion physics activities) showed that computers are really nifty.

I feel as if the motion physics activities have refreshed my knowledge of physics, but I don't feel that it was necessarily helpful to me. I haven't been able to get direct input from my answers to the questions; therefore, I don't know if I'm making progress or not.

I feel that this is not helpful to me because it is not done in context with any particular subject; and it has been done in such a manner as to not consider different learning environments or backgrounds.

They (motion physics activities) have allowed me to better understand the world around me.

**Intermediate Responses at Level_A of CRS_Dose, (High School Students):**

Yes. Because now I can understand the difference between force and momentum. I can tell you the difference between the two (force and momentum) compared to before (which I could not do) this computer program.

Being able to see them (physics activities) in action has helped me remember them.

No. I was never given any background information on my topic and feel that I was always sort of on the edge . . . guessing as to what I was supposed to do next without fully understanding what I had done previously.

Yes. In some ways they have. Have found them very fun and exciting.

Yes. They have refreshed some of the knowledge that I obtained years ago. They also help to put a visual image in your head.

No, not really. I already learned some of this and the rest I have not needed so far in life.

Yes. Because before I didn't know about or forgot about all of the lessons in motion and the other physics related elements that were taught to me through this activity. I think that it helped refresh my memory.

These activities have been helpful. Although I have had experience working with terms and formulas, in doing these assignments, my understanding of the topic is increased. But I was not taught anything new.

They have been helpful in determining the laws of chemistry and physics.
Yes. They have helped me learn new vocabulary words in science.
Yes. I have a little better understanding of momentum.

I don't take any physics classes.

It taught us how different energies are used to apply motion.
They have reinforced my knowledge of physics.
Yes. They helped me learn about physics because I learn more when I use computers.

They helped me to better understand motion in a vacuum and gravity of planets.

Not really, seeing that I did not learn much and that the courses were not specific in what they were teaching.
No.

Yes. (Motion physics) gives me a better explanation to the key terms in physics.

Not really. We have just been trying to figure out where we are supposed to be.

We have not taken Physics.
Yes, it helped me.

**Intermediate Responses at Level_B of CRS_Dose, (High School Students):**

No. I don't really understand it.

Yes. Things I didn't know about gravity that evolves around Earth; I know now and that is very interesting to me.

Sometimes I found difficulty in understanding exactly what the question was asking. But once I got a full grasp of what was going on, I was fine.

They would be helpful if someone taught along with them (physics activities) and explained what was happening in each program.

Yes. They helped me with understanding motion and weight and how they can throw each other off.
Yes. In a way it has (been helpful), because I didn't know as much as I do now.
Yes. They have helped me understand some things that I did not know before.
Yes. They have helped a little with some areas of physics but there is a lot more that I could/should know.
Yes. Because now I know at least a little bit more about momentum and mass than I did when I first came to the computer lab.
Yes. They have been somewhat helpful to me, because it's the way you figure out things and measure distance.
Yes. Because it's good to know how we move, how things fly and their importance.

No, not much. A lot of the stuff I had already learned in physics class.

I don't think that they have been helpful. They are hard to understand and they are stupid.

Yes, they do because they show me first hand what exactly the motions are and how they are used.
It helps me move faster.
Yes. It has slightly clarified my knowledge of motion.
They have been kind of helpful because before doing them I didn't know what motion really was. Now I understand a little.
I think that this has been a big help because I can see how motion works in today's world.
The motion physics activities have been helpful to me because I haven't taken physics and did not really understand physics.

I learned new methods of measuring.

We have learned more about how to use the computer programs than about science.

Yes. They helped me see just how physics works in regular activities.
Yes. Because they help me to better understand the terms and laws shown and explained.

**Intermediate Responses at Level_C of CRS_Dose, (High School Students):**

Yes and no. I have done all of these activities before in a physics class. I know most principles and objectives that we are trying to accomplish here. But it was interesting to go back over them and do these (motion physics) activities.

No. I do not understand how to do anything. Only one person to explain the rules to 15 kids. I lost interest quickly.

I have got to learn more about them (motion physics).

Yes. They have given me a hands-on experience without actually using my hands. I can set up a simulation and run it and if my experiment fails, I can hit the reset button and start all over in a matter of seconds instead of hours.

They were a refresher of my physics last year. The activities showed me how much I know and I learned last year that I can't remember now. Wonder if this is the same for all my classmates, or if I just didn't pay as much attention as I thought I was (paying) in physics class.

Yes. Because they help me to understand more completely about something.

No. Was taught some things that I needed a basic knowledge of physics to learn. I didn't have much basic knowledge to learn from these activities.

Yes. I better understand what I am doing in science when I have a visual activity.
Yes, I guess so.

No. They taught some things that I needed basic knowledge of physics to learn. I didn't have that much basic knowledge to learn from these activities.

I'm afraid it hasn't helped me at all.

Yes. They make the whole study of physics a lot easier to understand and to do.
Yes. It helped me learn how things move and what kind of motions it needs.
Yes. It lets us see how physics works.

No, they haven't.

They have been helpful in that I never had much experience with this kind of information before. I think these experiments helped in my understanding of motion.

Yes, because it's hands-on stuff.
Well, I have certainly learned things I did not know and I found the gravity project very interesting. But overall, it was a learning experience.

Don't know because neither of us has had physics yet and I don't have any science classes this year.
They have not been helpful at all.
Don't know.
No. I did not do it enough.
I don't know.
No, not really.
No, because they require a pre-understanding of everything.

No. I really don't think that a computer will teach me as well as a human teacher. I feel that to learn in the best possible manner, one must have interaction with another human being.

**Novice Responses at Level_A of CRS_Dose, (Middle School Students):**
All the little simulated activities we did helped me see what happens without actually having to go out in the open and do these.

No, because I really did not understand.

Yes, because it made science class more fun.

I know a little bit about physics now. Yes, they have been helpful to me. They have taught me mostly about the speeds of objects and how they move.

Yes, because I can see in what direction the object is going.

Yes. It has let me see physics in many different ways. It has let me see how the speed of an object affects physics. It has also shown me how important physics is to everyday life.

Yes. They have helped me. I learn better with hands-on activities.
Yes, because it has helped me to visualize things.
Yes. They have helped me understand (motion physics) better.
I have learned.
No.

Yes. The motion activities have been very helpful to me because they teach us lots of information.

Somewhat. Now I can understand more concepts. Neato mosquito!

Yes. They give an explanation on different subjects and they give a picture to relate to that explanation.

A little. They have helped me by showing me visual examples.

They sort of have been helpful to me. It tests the things that I know and help me learn about the things that I don't know at all. I can use the information that I learned in everyday life. I can use this information in several different places such as math, science, and how I think about things and try new things out.

Yes, because I get written information and visuals.
Yes

Yes, because they are learning and teaching in a fun way and they taught me a lot.
Now I understand physics better.
I feel that they have been somewhat helpful to me in the way that I know more than I did before.
Yes, (helpful) in the way that I now know how to use all those little things.

**Novice Responses at Level_B of CRS_Dose, (Middle School Students):**
A little bit. I understand a lot more.

It showed me many new things with the drawings because it actually moves and now (you see) how fast they go. And it shows you many ways you can find the answer. It's fun because it's like playing a computer game and not working, but you still have to answer correctly.

Yes, because I got to see the stuff straight forward.
I discovered new things but not much.
Yes. They are fun and when it's fun, I learn.

Yes. I think because it helps me understand it better.

We haven't had motion physics in science yet!

No. I honestly had no clue what was going on.
Not really helpful, but more fun . . . I guess.

Yep, they have helped.

Yes. I have learned a lot through this program.

Yes they have. Because they have helped us understand the way of motion and force.

Yes. Because I have learned about motion, momentum, inertia, and the forces of motion, I can now explain them somewhat.

Yes, all of them (motion physics activities). We feel that using the computer to learn is a lot better because it singles us out unlike in a classroom that has 30 some students.

I think motion physics activities have been very helpful because I now greatly understand momentum and gravity's effect on it.

In a way they have, but maybe if we spent more time on them it would help more. I don't think that I have learned much while working on the computer. However, I would like to continue working on it.

Yes. They made me realize the real effects of certain forces.

**Novice Responses at Level_C of CRS_Dose, (Middle School Students):**

Not really, because I already know a lot of the stuff that we are doing and I just feel that I am doing this again.

It brings back things I learned a couple of years ago in science. I learned a little bit about them (motion physics) in 4th and 5th grade. It (motion physics activities) made me want to learn because its fun.

Yes. They were fun and effective. They made me remember things.
Yes. I feel better about my knowledge in the science field.
Yes, because now I know what force is.

I don't know.
No, I do not.

Yes. It has taught me about momentum, force, gravity, inertia and lots of other scientific words that I didn't now their definitions before.

Yes. They have helped us in our physics activities. You get a hands-on experience.

Yes. They taught new things.

No.
No. They haven't been helpful because I really don't understand it.

They were a lot more fun than writing boring things down on paper. The pictures and graphics were really cool too. I did learn some neat stuff that I didn't know before. I was able to do hands-on activities, which I think help me learn.

Yes. I didn't have to interact with any people.

Yes. They have helped a lot by showing the formula for calculating momentum and by helping me to find out how to apply my new found knowledge. I have found out how inertia and mass effect how an object moves, or how far an object moves. I also learned what an impulse is.

Yes.
No, in no way.

**Learner Understanding--Sim_1:**
**Critical Thinking of Motion Physics by Expert, Intermediate, and Novice Learners**
**Query theme: 'Mass is a measure of inertia! '**
Query item using Balls--Sim_1:

Suppose there are two bowling balls at rest. One has a mass of 7 kg, the other a mass of 5 kg. Would there be a difference in the amount of force needed to roll each ball the same total distance? State whatever thoughts you used to arrive at a decision.

**Expert Responses at Level_A of CRS_Dose, (High School Physics Students):**

Yes. Because one would have less inertia so less effort would be needed to move it the same distance.

The bigger ball requires more effort to roll the same distance as a smaller ball, requiring less effort to accomplish the same end result.

You would need a greater amount of force to move the ball with a mass of 7 kg.

The effort would be different because the mass is different.

There would be a difference because it will take more force to move the 7 kg ball than to move the 5 kg ball.

If the same force is applied to both bowling balls, the lighter (5kg) will roll farther.

Yes. Because the lighter ball requires less initial kick to travel the same distance.

**Expert Responses at Level_B of CRS_Dose, (High School Physics Students):**

Yes. Because the larger ball requires more effort as it has a greater inertia and a greater mass.
Yes.

Yes. The smaller ball needs less effort to move.

A difference in the amount of effort needed to roll each ball for the same total distance would be needed. Since F = mg, a greater Force is required to suffice a larger mass.

Yes. They have different masses, thus needing different forces to move them the same distance.

**Expert Responses at Level_C of CRS_Dose, (High School Physics Students):**

Yes. The 7kg ball has more inertia and therefore needs more effort to be moved an equal distance.

Yes. The more massive bowling ball requires more effort because it has more inertia (resistance to change) due to its larger mass.

Yes. Because they have different masses, therefore they have different weights and would require different efforts to move them.

Yes. Because inertia is the resistance to move, and mass equals the inertia. Therefore the heavier bowling ball would be harder to move.

It would require more effort to roll the heavier ball.

**Intermediate Responses at Level_A of CRS_Dose, (High School Students):**

Yes. You would have to push the bigger ball harder to get it moving so a greater effort is required.

The 7kg ball resists motion more but it tends to stay in motion more than the 5kg ball.

One is heavier than the other.

Yes. Because the more mass, the more effort needed.

Yes. The ball with the mass of 7kg has more inertia than the ball with the mass of 5kg. Therefore it would take more force to propel the heavier ball the same distance as the lighter ball.

Yes. The heavier one would require more force to put it into motion.

**Intermediate Responses at Level_B of CRS_Dose, (High School Students):**
You would need more force for the seven pound ball.

The heavier the ball, the more effort it takes to move it.

Yes. The mass of the 7 kg ball would need more effort than the lighter ball.

No. I don't think there will be.

Yes. The heavier the object the more force and effort it will take to propel the object forward.

**Intermediate Responses at Level_C of CRS_Dose, (High School Students):**
Yes. There will be a difference because the 7kg ball needs more force than the 5kg ball.

Yes, there would. For a person to throw a ball with more mass, he would need to exert more force to lift the ball. But once the ball is in motion, the mass would cause the ball's speed to increase.

Yes. The heavier ball needs more force to move it the same distance.
Yes.

Yes. Because the effort of the initial kick is less on the smaller ball than the larger ball.

Yes. One has more inertia. The bigger ball has more inertia.

**Novice Responses at Level_A of CRS_Dose, (Middle School Students):**
Yes.
Yes. One has more mass and it is bigger.

**Novice Responses at Level_B of CRS_Dose, (Middle School Students):**
Yes there will be.

Yes. There would be a difference because one ball is lighter.

I don't know! I have not learned this yet!

**Novice Responses at Level_C of CRS_Dose, (Middle School Students):**

Yes. You would need more effort to roll 2 bowling balls with two different masses.

Yes. You would need more strength to push the ball that weighed 7 kg.

Yes. Because one is heavier than the other and it needs more push.
Yes.

**Learner Understanding--Sim_2:**
**Critical Thinking of Motion Physics by Expert, Intermediate, and Novice Learners**
**Query theme: 'Impulse causes motion! '**
Query item using Balls--Sim_2:

Suppose there are two bowling balls at rest. One has a mass twice the mass of the other. Would there be a difference in the total distance each ball travels if each ball receives the same impulse? State whatever thoughts you used to arrive at a decision.

**Expert Responses at Level_A of CRS_Dose, (High School Physics Students):**

No. The distance would be the same because the distance would be proportional.

Yes. The larger ball would travel a much shorter distance than the smaller ball.

Yes. The ball with twice the mass would travel twice as far.

Yes, there would be a difference.

If the impulse is enough to move the bowling balls significantly, then there would be a difference. The smaller ball would move further. But if the impulse is too small, then there would be no significant difference.

Yes. The ball that is twice as heavy will use more of the impulse in the act of starting the motion; therefore not having enough momentum to travel as far as the lighter ball.

Yes. There would be a difference in the total distance that each ball travels because the ball with the heavier mass takes more impulse to go the same length - the lighter ball needs less.

**Expert Responses at Level_B of CRS_Dose, (High School Physics Students):**

Yes. The lighter ball would go twice as far as the heavier ball.

The larger bowling ball would go half as far in everyday circumstances. But in a vacuum, the balls would continue traveling for infinity.

Yes. The larger ball wouldn't go as far as the smaller one.

Yes. A difference in the total distance each ball (rolls) with different masses would differ. The 1m ball would travel a longer distance because the impulse acting on it would use less initial force to move the object.

Yes. The larger mass would move farther than the smaller mass.

**Expert Responses at Level_C of CRS_Dose, (High School Physics Students):**

Yes. The more massive one wouldn't go as far as the less massive one.

Yes. The less massive (one) will go twice as far as the other.

Yes. The ball with a higher mass has a higher inertia, making it harder to move.

The lighter ball would move twice the distance.

Yes. There would be a difference. The heavier ball would travel less than the lighter ball, even though they received the same impulse.

**Intermediate Responses at Level_A of CRS_Dose, (High School Students):**

Yes. The lighter ball would go further because it takes less force to move it a certain distance.

Yes. The 2x mass ball resists change more than the other, so it rolls less distance.

Yes. One has more momentum.
Yes. The smaller one would go further because it's lighter.

The ball with the lighter mass would travel twice as far as the ball with the greater mass. The ball with the greater mass has twice the inertia of the ball with the lighter mass so it would take twice the impulse to propel it the same distance as the lighter ball.

Yes. The ball with the lesser mass would travel farther.

**Intermediate Responses at Level_B of CRS_Dose, (High School Students):**
They would go farther based on the mass of each ball.

The lighter ball would travel farther.

No. It would be the same.

Yes. The heavier ball wouldn't roll as far because the heavier the ball the more force is required to propel it.

**Intermediate Responses at Level_C of CRS_Dose, (High School Students):**
The distance for the two balls is different. The 1 m ball goes farther than the 2 m ball.

Yes, there would be a difference. If you kicked a soccer ball and then kicked a bowling ball, you would notice a great difference. First you would probably notice the extreme pain you acquired from kicking the bowling ball. But after you were over the shock, you would notice that the soccer ball went a great deal further than the bowling ball because the bowling ball is heavier than the soccer ball and therefore would need more force to move.

Yes. The heavier ball will not move as far because it is heavier and it needs more force to move it the same distance.

Yes. It takes more initial kick to get the larger ball to move the same distance as the smaller ball.

Yes. Because the heavier one will not move as far. The bigger (lighter) ball would roll faster than the smaller (heavier) ball.

**Novice Responses at Level_A of CRS_Dose, (Middle School Students):**
Yes. (2 times)

**Novice Responses at Level_B of CRS_Dose, (Middle School Students):**
Yes there will be.
No. (2 times)

**Novice Responses at Level_C of CRS_Dose, (Middle School Students):**
Yes. One would go farther than the other one.

Yes. The lighter ball would go farther.

Yes. Because one is heavier and would need more push to go the same distance as the one of less weight.

# APPENDIX P
# COMPREHENSIVE LIST OF STUDY ACRONYMS

ABE ability-belief-expertise model for knowing and learning.

AbI learner ability index in science and mathematics.

AtI learner attitude index towards science and mathematics.

ACM analytical caring mind; an active state of the mind desired for learners of science and mathematics.

AD affective domain of the learner; the learner profile that plays a dominant role in learner perspectives, beliefs, opinions, attitudes, and feelings.

ADA a graphical way for evaluating learner viewpoints which graphically illustrates learner non-response as a measurable departure from the diagonal; graph points are identified with learner response (agree, disagree) data sets.

ADM affective domain modeling; models affective learning profiles of students; works with learner feelings, opinions, and related emotional capacities; models subjective methods of expressing oneself with feelings, forming opinions, and carrying out actions based on some underlying belief system.

AFM activity-based learning about force and motion concepts.

AbI learner ability index; the achievement and aptitude a learner demonstrates for knowledge, skill, understanding, and performance in a specific area; ability to derive meaning from the structure and function of a system.

AtI learner attitude index; the perceptions and expectations a learner expresses towards learning and strategies for engaging new learning frontiers.

ALP learner awareness of own learning progress; a learner expectation cluster used in the study.

ALPT affective learning profile tools for modeling, in a subjective way, a state of feeling, opinions, and emotions as expressed by the learner.

ANA a graphical way for evaluating learner viewpoints which graphically illustrates conservation of learner response and non-response states along the diagonal; graph points are identified with learner response (agree, non-agree) data sets.

ATE analytical tool effect; recognizable pattern variations of data attributable, or influenced in some direct way by the type of analytical tool (labeled picture, illustrated table, dynamic -linked graph) available to the learner for solving force and motion problems, relative to an expert response in the study population.

BI learner belief index; associated learner conviction and how consistent the learner is on making a specific choice or providing a specific opinion; has both event and temporal components for identifying learner behavior.

BNB race-based learner categories identified for black (B) and non-black (NB) learners in the study population.

CAD cognitive (C) and affective (A) domains (D) for learning; used to model student learning profiles.

CBI cognitive-belief index.

CBL computer based laboratory; uses handheld data sensing and collection devices.

CBM cognitive-belief model; a knowing model.

CCE control-context-expertise model for knowing and learning.

CDL context dose level; also CRS dose level.

CD cognitive domain of the learner; the learner profile that plays a dominant role in learner knowledge, understanding, and powers of reasoning.

CDM cognitive domain modeling; models cognitive learning profiles of students; works with learners' thoughts, ideas, and related conceptual capacities; models objective methods of expressing oneself conceptually and having a sense of understanding for thematic presentations of information.

ChE challenge effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance by challenge level difficulty, relative to an expert response in the study population.

CxE context effect; recognizable pattern variations of data attributable, or influenced in some direct way by contextual-imagery control parameters, relative to an expert response in the study population.

CtI learner control index; ranges from intrinsic (more positive and desirable) to extrinsic (less positive and desirable); intrinsic learners become bored less often, more readily involve themselves in learning opportunities, seek out solutions, and more eager to take on new challenges.

CxI context index associated with level of real and virtual world being experienced; ranges from more real world to more virtual world.

CcL concept learning; developing an understanding for the underlying conceptual themes that model or explain why some process occurs.

CxL context learning; developing an understanding through real world linkages for the underlying conceptual themes that model or explain why some process occurs.

CL_A context-based activity dose level A; the study control context level.

CL_B context-based activity dose level B; the study lower experimental context level.

CL_C context-based activity dose level C; the study higher experimental context level.

CLC context level criteria; criteria used to discriminate on context dose level.

CLE contextual learning environment.

CLM constructivist learning model; also, scientific constructivist learning model; aligned with the belief that useful learning in science occurs when the learner constructs his/her own knowledge base of scientific constructs through inquiry and discovery; focuses on experiential learning opportunities.

CLP cognitive learning profile; uses tools for modeling, in an objective way, a state of knowing, understanding, and reasoning as expressed by the learner.

COOL being in control of one's own learning; intrinsic control comes more from the learner's own capacities than from outside forces; extrinsic control comes more from outside forces than from the learner's own capacities.

COU a learner's center of the universe; learner preferred space and time.

CRI context-rich imagery available for learner imprinting in a way that it can be more readily assimilated into the learner's own repertoire of imagery resources.

CRS contextual-imagery referent system; imagery which provides meaning in context for an event or problematic circumstance and linkages that help the learner make connections between real world happenings and their underlying concepts; three CRS dose levels were created for this study; the levels increased in contextual-imagery from A to B to C (A<B<C).

CRSM contextual-imagery referent system learning model.

CRSD contextual-imagery referent system dose level.

CTL contextual teaching and learning; a schooling initiative for experiential learning being promoted at the federal level through the Department of Education.

CV conviction expressed by the learner.

CVS conviction shift experienced by the learner.

DART directed activity reading text.

DARV directed activity reading visuals.

DL dose level; associated with context levels A, B, and C.

DTP dynamic-thought-plume; learner's active mental state of the dynamic-knowing model developed for this study, nicknamed galaxy-of-the-mind (GOM).

DKM dynamic-knowing model.

DMLP dark matter of learner performance; analogous to learner non-response core present in a GOM model.

EKM empirical knowing model; theoretical model whose functional behaviors are consistent with empirical expressions grown from authentic, real data sets.

ERR expert-referent response; a response coming from experts in the study population that explains the function, form, and meaning of conceptual themes; this expert response is said to originate from the study population of learners; hence, learner response occurring in the population can be referred back to this expert response; the expert response provides a ceiling towards which to focus learner goals and from which to measure learner performance in the study population.

EC expectation clusters (such as SMT, PSA, ALP, TLT) used to assess learner perceptions.

EG expectation gaps exhibited by learners in some recognizable and measurable way as noticeable age-related differences in perceptions and expectations identified from response data for learners of science and mathematics.

EI learner expert index associated with learner type (LT) and formal level studied (FLS) in science, mathematics and, technology (SMT).

ELP experiential learning programs; learner-centered through real and virtual worlds.

FLS formal level studied in science and mathematics; novice (N), intermediate (I), expert (E) learners of science and mathematics; frequently analogous to school level: middle school (MS) learners as N, high school (HS) learners as I, high school physics (HSP) learners as E.

FLSp fine-line-splitting of learner response groups; graphical way of presenting and analyzing empirical data on learning systems.

FMS force and motion systems.

FOR frame-of-reference or reference frame.

FPL finger-printing learning; graphical way of presenting and analyzing empirical data on learning systems.

FR favorable response from learners relative to an expert response; a response made by a learner in the study population which is aligned with a response to the same set of query items by an expert group from the same study population; the expert group in this study was identified from learners having had or currently taking a high school physics course.

ft a surrealistic field-trip that suggests learner immersion in a force and motion human flight experience of hang gliding which includes interactive context-rich tutorials on force and motion; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

GDL guided discovery learning; opposed to free discovery learning strategies; associated with the scientific constructivist model of learning.

GE growth effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance by learner age level in science and mathematics, relative to an expert response in the study population and/or to the context dose level (CDL).

GOM galaxy-of-the-mind knowing model; a knowing model visualized as a dynamic globe which identifies the learner's mental efforts structured by continuous factors describing a triple-axis coordinate system from real to virtual worlds, from intrinsic to extrinsic control, and from being less expert to more expert in having a mental capacity for knowing, understanding, and forming convictions about phenomena in real, virtual, and imagined worlds; pictured as being spherical in shape but having a compliant surface capable of changing shape required by the learner's level of active learning engagement; has both temporal and spatial dimensions and capacity for thought structure overlays.

GPH dynamically-linked graph.

HFM human flight model; associated with ft-task activities.

IDLG identify with diverse learner groups; learner homogeneous groupings (LHG) as NIE, PG, MF, and BNB were identified as root LHGs' in the study; sub-groups such as NP, NG, IP, IG, and EG were formed from the root groups.

ILD Interactive Laboratory Demonstration; a demonstration involving the audience.

IMM interactive multi-media; an electronic medium, rich in contextual imagery, which entices and invites the learner to engage in learning through inquiry.

IS instructional strategies used to guide and direct learning processes.

ISM inquiry-based simulation models; used for instructional strategy modeling.

KBS knowledge-belief system present in learner conviction; the extent by which ones knowledge influences what one believes to be true and ones belief influences what one knows to be true.

LA learner ability in science and mathematics (NP, NG, IP, IG, EG).

LAnE learner age in science and mathematics normalized to an expert group.

LCv learner conviction; a mental state expressed by the learner as a response that is either right or wrong concerning a learner's achievement; also, a learner response that either agrees or disagrees on some viewpoint expressed as a learner's perspective.

LCL learner confidence level; the degree to which a learner is certain or expresses some concern for doubt regarding a conviction that was made, a position that was taken, or a viewpoint that was expressed.

LCvS learner conviction-shift; a measurable change that a learner makes towards or away from the way experts are said to view and understand a set of concepts, a spatial and temporal event, or some phenomena under study; a shift in learner performance or perception from one CRS dose level to another.

LD learning domains; such as affective and cognitive domains of a learner.

LGF LoGit Function; natural logarithm of the odds; mathematical modeling of parameters in the study using a probability expression.

LHG learner homogeneous groupings such as NIE, PG, MF, and BNB; sub-groups were formed from these root groups such as NP, NG, IP, IG, and EG; each root group defines the entire study population.

LI learner imagery; imagery which the learner readily recognizes as being part of the spatial and temporal patterns recognizable to the mind's eye or otherwise retrievable from the learner's mental storage system.

LKS learner knowledge-shift; analogous to learner conviction-shift; a shift away from (negative) or towards (positive) the knowledge level experts have of a particular conceptual topic where both learner and expert responses come from the same study population.

LLC learner locus of control; the extent to which the learner takes accountability and responsibility for his or her own learning and or actions; learner locus of control is said to be more intrinsic for learners who have more self-efficacy, responsibility, and accountability for their learning and less dependent on others in achieving successful outcomes; locus of control is said to be more extrinsic for learners who tend to be less responsible for their own learning and more dependent on others for their successful learning outcomes.

LNCv learner non-conviction; the lack of ability to make a decision and provide a response regarding that decision, be it right or wrong; also, having a lack of opinion on holding a viewpoint and expressing feelings that are neither favorable nor non-favorable regarding the opinion; may be aligned with leaner non-response since a decision or viewpoint cannot be identified for either of these response options.

LNR learner non-response; a measurable lack of response to some query present in the study population; learner withholds a selection or opinion and/or makes no acknowledgment of the query being presented; the non-ignorable, non-response of homogeneous groups which calls on a third probability element for characterizing learner response systems as being trinomial rather than the traditional binomial probability response system.

LPc learner perception; learner's immediate point of view of a specific event; how a learner actively views and sees an event being observed.

LPf learner performance; learners response to queries on force and motion.

LPs learner perspective; how the learner integrates events into the bigger picture; taking all factors of importance to the learner, the position a learner takes on the occurrence or happening of an event.

LPcS learner perception shift across context dose and/or across time, relative to the expert response, relative to the control dose level, or any measurable spatial or temporal parameter accessible to the study as learner views on usage of technology as tools for learning force and motion concepts.

LPfS learner performance shift across context dose and/or across time, relative to the expert response and to control dose level as well as any measurable spatial or temporal parameter accessible to the study, such as problem difficulty level.

LR learner response coming from the study population which can be placed in root groups and sub-groups of learners belonging to that population and which can be evaluated for some status of learner conviction such as a favorable response (FR), a non-favorable response (NFR), a correct or right response (R), and a wrong or incorrect response (W).

LRA logistic regression analysis; an advanced statistical method for studying observed patterns of learner responses in the study population.

LT learner type as indicated by success in science and mathematics: good (G), an above average student; poor (P), an average or below average student.

mb model building of different gravitational worlds; activity provided learners with opportunities for controlling and observing the effects of mass and motion attributes of orbiting bodies and the invisible force of gravitation that governs their planetary-like movement; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

MC mental capacity by which a learner can store, retrieve, and utilize information.

MCI multi-contextual instruction; providing opportunities for experiential learning using activities that provide a diverse set of context-based, visual imagery associated with real world events relevant to the concepts to be learned.

MCL multi-contextual learning; learning involving diverse context-based experiences.

MCT multi-contextual teaching; teaching involving diverse context-based strategies.

ME the mind's eye as seen by the learner.

MER more expert-like response; learner progress and positive conviction shifts are said to occur as the learner response becomes more aligned with an expert response identified in the study population for conceptual themes being studied; learner response becomes more favorable to the measured response held by experts present in the same study population.

MF gender-based learner categories of male (M) and female (F).

MH mental habits of the mind as exhibited by the learner.

MIM Mental Imagery Model.; learner response to a task follows a common sequential order using selected mental images.

ML mental labor which the learner exerts using the mind's functions.

MM multimedia; an integrated media approach for representing an event.

MtM metamodel; a collection of models and modeling tools.

NCV non-conviction expressed by the learner as failing to make a decision or not being convinced one way or the other on an outcome.

NFR non-favorable response from learners; a learner response that is not aligned with an expert response coming from the same study population and responding to the same instrument query items for which learner response is evaluated.

NIE novice (N), intermediate (I), and expert (E) learners in the study population providing the performance and perspective criteria-based data sets.

NPLS nurturing a progression of learners towards success; providing learners at different ability and growth levels with tools and an awareness of the usage of those tools; utilizing effective learning strategies that are more likely to promote learner academic success and mastery of concepts; utilizes CAD, CRS, and GOM learning models.

NRC non-response core; a spatial region of the dynamic-knowing model (GOM) which identifies the extent of learner non-conviction, lack of mental effort, and lack of mental labor towards identifying, reflecting, and understanding concepts and conceptual themes desired to be learned.

NRE non-response effect presented by learners in some recognizable and measurable way as noticeable from data patterns on ADA and RW graphs identified from response data for learners of science and mathematics, relative to an expert response in the study population; like NRG.

NRG the non-response gap associated with the degree of learner non-response present in the study population; the non-response gap varies inversely with learner response; learner success tends to become more frequent as this gap becomes smaller using CRS-learning modeling strategies; like NRE.

OD odds; ratio of probability an event is true to the probability an event is false; uses frequencies of occurrence and non-occurrence of an event in a population to ascertain the chance an event is true or false.

OMM orbital mechanical modeling of active learning states using the GOM model.

OR odds ratio; a mathematical expression identifying a learner's performance or batting average as a learner odds relative to an expert odds; the odds, 'O', is itself a ratio of success to failure occurrences of the target groups in the study population.

PC polar coordinates; parameters for representing regions of space using distance from an origin and two angular variables used to identify rotation about that origin.

PER physics education research; an emerging field of physics research.

PERG physics education research groups; physicists involved in the PER initiative.

PG poor (P) and good (G) learners of science and mathematics as identified in the study population.

PIC labeled picture.

pif problems sets identified as query items on momentum (p), impulse (i), and force (f) for learner performance assessment used in the study.

PLC perceived locus of control as held by the learner; a learner expectation cluster based on learner viewpoint used in the study.

POV point-of-view or viewpoint.

PR pattern recognition; ability to associate elements of a system into a recognizable pattern for memory storage, retrieval, and mental utilization.

PS problem sets on force and motion used to assess learner performance.

PSv problem solving.

PSA problem solving ability as perceived by the learner; a learner expectation cluster used in the study.

pw probeware utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

PfG performance gaps exhibited by learners in some recognizable and measurable way as noticeable age-related differences in the conceptual understanding of force and motion systems identified from response data for learners of science and mathematics.

PrG perception gaps exhibited by learners in some recognizable and measurable way as noticeable age-related differences in perceptions and expectations identifiable from response data for learners of science and mathematics.

Q_A quad_A cluster of workstations designed for context dose CL_A.

Q_B quad_B cluster of workstations designed for context dose CL_B.

Q_C quad_C cluster of workstations designed for context dose CL_C.

QTM quantum theory modeling; used in physics for modeling discrete energy states; can be used by learning theory to model discrete active learner states.

REAL real-world, experiential, active learning opportunities for students learning science and mathematics.

RLE response of local experts in the study population.

RM repeated measure; a measurement taken on a separate level of the same category, as identified for a factorial design, and used for statistical analysis.

RNR response and non-response present within homogeneous groupings of learners identified for the study population.

RS_A relative success on query items of learners to experts having CRS dose level A.

RS_B relative success on query items of learners to experts having CRS dose level B.

RS_C relative success on query items of learners to experts having CRS dose level C.

rw real-world like computer simulations of force and motion events that tend to be more commonplace to everyday experiences of the students; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

RW a scoring rubric which accounts for right (R) and wrong (W) responses, but learner non-responses (O, also NR) are assigned to the wrong response category in arriving at a learner score on a query instrument.

RWO a scoring rubric which accounts for learner non-responses (O, also NR) as well as right (R) and wrong (W) responses in arriving at a learner score on a query instrument.

SE success effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance by degree of success in learning force and motion concepts, relative to an expert response in the study population and/or to the context dose level (CDL).

sf star-field presented within a 3-D system as a rotating manipulative to promote learner awareness of making comparative observations of systems under study from a variety of different perspectives; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

SLM self-contained laboratory model; applied to a contextual learning task.

SMT a learner science, mathematics, and technology expectation cluster.

SOL science of learning; discovering what it means to learn; processes and methods used to model and understand how one goes about learning to learn.

spex expectations learners have for becoming actively engaged in their own learning; expectation clusters identified for this study include PSA, ALP, TLT, and SMT.

STA spatial and temporal analysis; analysis that accounts for observed changes in a system which are both space and time dependent.

TBL illustrated data table.

TE technology effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance and learner perspectives influenced by technology specific factors, relative to an expert response in the study population.

TIMMS Third International Measurement of Mathematics and Science.

TLS teaching and learning strategies.

TLT learner perceived expectations for the usage of technology as learning tools; a learner expectation cluster used in the study.

TM thinking model; promotes the belief that student response to a task follows a common sequential order using selected mental images.

TTC technology transfer to the curriculum; an initiative being promoted at the national level by the International Society for Technology in Education (ISTE).

VTIA-1 visual tools for inspiring analysis; usage of dynamic-graph-linked clips, tables, and pictures which help the learner make associations between a real world event and an analytical representation of that event using multicontextual visual tools; these visual tools include CRS dose levels, problem challenge levels, visual_IMM levels, and visual_analytical levels.

VTIA-2 visual tools for improving attitude; usage of context-rich imagery and interactive multi-media in ways that offer learners invitations to inquiry; these visual tools include learner technology attitude (TLT), confidence level (LCL) control and expectations (PLC, PSA, ALP), and learner non-response (NRG).

WVI learner world view index; an index measured on a continuum, ranging from more real to more virtual, used to characterize how a learner views the world.

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## BIOGRAPHICAL SKETCH

Sara-Maria Francis Deese Becht was born August 21, 1943, in Mobile, Alabama. She moved with her family to Melbourne, Florida, in 1950. She demonstrated an early interest for scientific research through ozone laboratory science fair projects and a talent search paper, Ozone--From Scientific Error to Space Age Plan. In 1961, she graduated with honors from Saint Anastasia High School, Fort Pierce, Florida. During the summer of 1961, she took courses at Brevard Engineering College in Melbourne. In September 1961, she began studies at Spring Hill College, Mobile, Alabama, where she received her degree Bachelor of Science with honors in May 1965, her major fields being in physics and chemistry and a minor in mathematics. She was vice-president of American Institute of Physics Student Section at Spring Hill College from 1963 to 1964. During her sophomore and junior years, she initiated projects involving the design, construction and testing of both gas and solid state lasers. During the summers of 1962, 1963, and 1964, she did course work at George Washington University, Washington D. C.

She came to the University of Florida in September 1965 to do graduate work in the Department of Nuclear Engineering Sciences, now Nuclear and Radiological Engineering. While in the Nuclear Engineering Sciences Department, she held a Graduate Assistantship, a College of Engineering Fellowship, and an Atomic Energy Commission Traineeship. Her first research study was on the heat transfer dynamics of a water droplet on a hotplate. Her interest in fusion led her to study plasma systems.

She received the degree Master of Science in Engineering with a major in plasma physics and minor in nuclear engineering. She designed, built, tested, and analyzed the first contained uranium plasma system at the University of Florida. Her thesis for the masters program was Development of a Plasma Chamber and Determination of the Radial Temperature Distribution of Mercury and Uranium Plasma Sources by Comparative Spectroscopic Analysis. During the succeeding years she continued graduate work on doctoral programs, majoring first in plasma physics and later in chemical physics. She studied total decomposition and real-time fragmentation of simple chloro-fluorocarbons using a computer interfaced hybrid gas chromatographic--time-of-flight mass spectrometer system, for assaying dosimetry samples and for monitoring mass fragments after injecting samples through a fast-flow microwave discharge system.

During those years, she also became involved with computer technology in education while raising a family. She carried out several research studies in instructional technology for the Florida Department of Education and made many presentations involving instructional technology at Florida Educational Technology Conferences, Florida Association of Science Teachers Conferences and National Science Teachers Association Conferences. She completed a graduate program for the degree Specialist in Education with a major in science education from the Department of Instruction and Curriculum. She has taught courses at the university, community college, and high school levels in the fields of computer science, physics, and chemistry.

She has had experience as a biochemist in the U.S. Department of Agriculture (USDA) and the University of Florida College of Veterinary Medicine (CVM). She performed studies at the insect taxonomy lab at USDA where she utilized a

computerized, integrated capillary gas chromatography--high-pressure liquid chromatography--diode array mass spectrometer (GC:HPLC-DA/MS) system for the analysis of insect extracts. She then transferred to a nutrition/lipoprotein biochemistry lab at CVM in the Department of Physiological Sciences where she performed clinical type sample analysis of blood plasma using electrophoresis and an absorption spectrophotometer for the quantitative measurement, using a capillary GC system, of fatty acid methyl esters derived from food extracts. Her research next carried her to a cardiovascular research lab where she developed and conducted methods using PAGE electrophoresis of ventricle heart tissue extracts for the assay of cardiac proteins (HC myosin). She then made a non-automated HPLC station functional from a quality control (QC) standpoint and performed basic drug assays for Lidocaine on blood plasma extracts.

Currently, she is completing her dissertation in the School of Teaching and Learning, majoring in curriculum and instruction with minors in both physics and chemistry. Her dissertation for the doctoral degree, Modeling the Effects of Multicontexual Physics Instruction on Learner Expectations and Understanding of Force and Motion Systems, connects the fields of science education and instructional technology using modeling theory on the science of learning. She is a member of many professional organizations and societies including the following: National Science Teachers Association, 1987 - present; Florida Association of Science Teachers, 1987 - present; American Association of Physics Teachers, 1995 - present; American Chemical Society, 1969-72; 1995 - present; American Organization of Analytical Chemist, 1995 - present; American Nuclear Society, 1965-69; 1988 - present; American Institute of Physics, 1961-65; 1995 - present; Kappa Delta Pi (1989); Phi Kappa Phi (1988); and Phi Delta Kappa (1981).

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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This dissertation was submitted to the Graduate Faculty of the College of Education and to the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

December, 1999

Dean, College of Education

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IMM interactive multi-media; an electronic medium, rich in contextual imagery, which entices and invites the learner to engage in learning through inquiry.

IS instructional strategies used to guide and direct learning processes.

ISM inquiry-based simulation models; used for instructional strategy modeling.

KBS knowledge-belief system present in learner conviction; the extent by which ones knowledge influences what one believes to be true and ones belief influences what one knows to be true.

LA learner ability in science and mathematics (NP, NG, IP, IG, EG).

LAnE learner age in science and mathematics normalized to an expert group.

LCv learner conviction; a mental state expressed by the learner as a response that is either right or wrong concerning a learner's achievement; also, a learner response that either agrees or disagrees on some viewpoint expressed as a learner's perspective.

LCL learner confidence level; the degree to which a learner is certain or expresses some concern for doubt regarding a conviction that was made, a position that was taken, or a viewpoint that was expressed.

LCvS learner conviction-shift; a measurable change that a learner makes towards or away from the way experts are said to view and understand a set of concepts, a spatial and temporal event, or some phenomena under study; a shift in learner performance or perception from one CRS dose level to another.

LD learning domains; such as affective and cognitive domains of a learner.

LGF LoGit Function; natural logarithm of the odds; mathematical modeling of parameters in the study using a probability expression.

LHG learner homogeneous groupings such as NIE, PG, MF, and BNB; sub-groups were formed from these root groups such as NP, NG, IP, IG, and EG; each root group defines the entire study population.

LI learner imagery; imagery which the learner readily recognizes as being part of the spatial and temporal patterns recognizable to the mind's eye or otherwise retrievable from the learner's mental storage system.

LKS learner knowledge-shift; analogous to learner conviction-shift; a shift away from (negative) or towards (positive) the knowledge level experts have of a particular conceptual topic where both learner and expert responses come from the same study population.

LLC learner locus of control; the extent to which the learner takes accountability and responsibility for his or her own learning and or actions; learner locus of control is said to be more intrinsic for learners who have more self-efficacy, responsibility, and accountability for their learning and less dependent on others in achieving successful outcomes; locus of control is said to be more extrinsic for learners who tend to be less responsible for their own learning and more dependent on others for their successful learning outcomes.

LNCv learner non-conviction; the lack of ability to make a decision and provide a response regarding that decision, be it right or wrong; also, having a lack of opinion on holding a viewpoint and expressing feelings that are neither favorable nor non-favorable regarding the opinion; may be aligned with leaner non-response since a decision or viewpoint cannot be identified for either of these response options.

LNR learner non-response; a measurable lack of response to some query present in the study population; learner withholds a selection or opinion and/or makes no acknowledgment of the query being presented; the non-ignorable, non-response of homogeneous groups which calls on a third probability element for characterizing learner response systems as being trinomial rather than the traditional binomial probability response system.

LPc learner perception; learner's immediate point of view of a specific event; how a learner actively views and sees an event being observed.

LPf learner performance; learners response to queries on force and motion.

LPs learner perspective; how the learner integrates events into the bigger picture; taking all factors of importance to the learner, the position a learner takes on the occurrence or happening of an event.

LPcS learner perception shift across context dose and/or across time, relative to the expert response, relative to the control dose level, or any measurable spatial or temporal parameter accessible to the study as learner views on usage of technology as tools for learning force and motion concepts.

LPfS learner performance shift across context dose and/or across time, relative to the expert response and to control dose level as well as any measurable spatial or temporal parameter accessible to the study, such as problem difficulty level.

LR learner response coming from the study population which can be placed in root groups and sub-groups of learners belonging to that population and which can be evaluated for some status of learner conviction such as a favorable response (FR), a non-favorable response (NFR), a correct or right response (R), and a wrong or incorrect response (W).

LRA logistic regression analysis; an advanced statistical method for studying observed patterns of learner responses in the study population.

LT learner type as indicated by success in science and mathematics: good (G), an above average student; poor (P), an average or below average student.

mb model building of different gravitational worlds; activity provided learners with opportunities for controlling and observing the effects of mass and motion attributes of orbiting bodies and the invisible force of gravitation that governs their planetary-like movement; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

MC mental capacity by which a learner can store, retrieve, and utilize information.

MCI multi-contextual instruction; providing opportunities for experiential learning using activities that provide a diverse set of context-based, visual imagery associated with real world events relevant to the concepts to be learned.

MCL multi-contextual learning; learning involving diverse context-based experiences.

MCT multi-contextual teaching; teaching involving diverse context-based strategies.

ME the mind's eye as seen by the learner.

MER more expert-like response; learner progress and positive conviction shifts are said to occur as the learner response becomes more aligned with an expert response identified in the study population for conceptual themes being studied; learner response becomes more favorable to the measured response held by experts present in the same study population.

MF gender-based learner categories of male (M) and female (F).

MH mental habits of the mind as exhibited by the learner.

MIM Mental Imagery Model.; learner response to a task follows a common sequential order using selected mental images.

ML mental labor which the learner exerts using the mind's functions.

MM multimedia; an integrated media approach for representing an event.

MtM metamodel; a collection of models and modeling tools.

NCV non-conviction expressed by the learner as failing to make a decision or not being convinced one way or the other on an outcome.

NFR non-favorable response from learners; a learner response that is not aligned with an expert response coming from the same study population and responding to the same instrument query items for which learner response is evaluated.

NIE novice (N), intermediate (I), and expert (E) learners in the study population providing the performance and perspective criteria-based data sets.

NPLS nurturing a progression of learners towards success; providing learners at different ability and growth levels with tools and an awareness of the usage of those tools; utilizing effective learning strategies that are more likely to promote learner academic success and mastery of concepts; utilizes CAD, CRS, and GOM learning models.

NRC non-response core; a spatial region of the dynamic-knowing model (GOM) which identifies the extent of learner non-conviction, lack of mental effort, and lack of mental labor towards identifying, reflecting, and understanding concepts and conceptual themes desired to be learned.

NRE non-response effect presented by learners in some recognizable and measurable way as noticeable from data patterns on ADA and RW graphs identified from response data for learners of science and mathematics, relative to an expert response in the study population; like NRG.

NRG the non-response gap associated with the degree of learner non-response present in the study population; the non-response gap varies inversely with learner response; learner success tends to become more frequent as this gap becomes smaller using CRS-learning modeling strategies; like NRE.

OD odds; ratio of probability an event is true to the probability an event is false; uses frequencies of occurrence and non-occurrence of an event in a population to ascertain the chance an event is true or false.

OMM orbital mechanical modeling of active learning states using the GOM model.

OR odds ratio; a mathematical expression identifying a learner's performance or batting average as a learner odds relative to an expert odds; the odds, 'O', is itself a ratio of success to failure occurrences of the target groups in the study population.

PC polar coordinates; parameters for representing regions of space using distance from an origin and two angular variables used to identify rotation about that origin.

PER physics education research; an emerging field of physics research.

PERG physics education research groups; physicists involved in the PER initiative.

PG poor (P) and good (G) learners of science and mathematics as identified in the study population.

PIC labeled picture.

pif problems sets identified as query items on momentum (p), impulse (i), and force (f) for learner performance assessment used in the study.

PLC perceived locus of control as held by the learner; a learner expectation cluster based on learner viewpoint used in the study.

POV point-of-view or viewpoint.

PR pattern recognition; ability to associate elements of a system into a recognizable pattern for memory storage, retrieval, and mental utilization.

PS problem sets on force and motion used to assess learner performance.

PSv problem solving.

PSA problem solving ability as perceived by the learner; a learner expectation cluster used in the study.

pw probeware utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

PfG performance gaps exhibited by learners in some recognizable and measurable way as noticeable age-related differences in the conceptual understanding of force and motion systems identified from response data for learners of science and mathematics.

PrG perception gaps exhibited by learners in some recognizable and measurable way as noticeable age-related differences in perceptions and expectations identifiable from response data for learners of science and mathematics.

Q_A quad_A cluster of workstations designed for context dose CL_A.

Q_B quad_B cluster of workstations designed for context dose CL_B.

Q_C quad_C cluster of workstations designed for context dose CL_C.

QTM quantum theory modeling; used in physics for modeling discrete energy states; can be used by learning theory to model discrete active learner states.

REAL real-world, experiential, active learning opportunities for students learning science and mathematics.

RLE response of local experts in the study population.

RM repeated measure; a measurement taken on a separate level of the same category, as identified for a factorial design, and used for statistical analysis.

RNR response and non-response present within homogeneous groupings of learners identified for the study population.

RS_A relative success on query items of learners to experts having CRS dose level A.

RS_B relative success on query items of learners to experts having CRS dose level B.

RS_C relative success on query items of learners to experts having CRS dose level C.

rw real-world like computer simulations of force and motion events that tend to be more commonplace to everyday experiences of the students; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

RW a scoring rubric which accounts for right (R) and wrong (W) responses, but learner non-responses (O, also NR) are assigned to the wrong response category in arriving at a learner score on a query instrument.

RWO a scoring rubric which accounts for learner non-responses (O, also NR) as well as right (R) and wrong (W) responses in arriving at a learner score on a query instrument.

SE success effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance by degree of success in learning force and motion concepts, relative to an expert response in the study population and/or to the context dose level (CDL).

sf star-field presented within a 3-D system as a rotating manipulative to promote learner awareness of making comparative observations of systems under study from a variety of different perspectives; utilized during context-rich hands-on learning activities associated with three dose levels of contextual-imagery referent systems.

SLM self-contained laboratory model; applied to a contextual learning task.

SMT a learner science, mathematics, and technology expectation cluster.

SOL science of learning; discovering what it means to learn; processes and methods used to model and understand how one goes about learning to learn.

spex expectations learners have for becoming actively engaged in their own learning; expectation clusters identified for this study include PSA, ALP, TLT, and SMT.

STA spatial and temporal analysis; analysis that accounts for observed changes in a system which are both space and time dependent.

TBL illustrated data table.

TE technology effect; recognizable and measurable variations in data patterns which can be attributed to study design parameters assessing learner performance and learner perspectives influenced by technology specific factors, relative to an expert response in the study population.

TIMMS Third International Measurement of Mathematics and Science.

TLS teaching and learning strategies.

TLT learner perceived expectations for the usage of technology as learning tools; a learner expectation cluster used in the study.

TM thinking model; promotes the belief that student response to a task follows a common sequential order using selected mental images.

TTC technology transfer to the curriculum; an initiative being promoted at the national level by the International Society for Technology in Education (ISTE).

VTIA-1 visual tools for inspiring analysis; usage of dynamic-graph-linked clips, tables, and pictures which help the learner make associations between a real world event and an analytical representation of that event using multicontextual visual tools; these visual tools include CRS dose levels, problem challenge levels, visual_IMM levels, and visual_analytical levels.

VTIA-2 visual tools for improving attitude; usage of context-rich imagery and interactive multi-media in ways that offer learners invitations to inquiry; these visual tools include learner technology attitude (TLT), confidence level (LCL) control and expectations (PLC, PSA, ALP), and learner non-response (NRG).

WVI learner world view index; an index measured on a continuum, ranging from more real to more virtual, used to characterize how a learner views the world.

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## BIOGRAPHICAL SKETCH

Sara-Maria Francis Deese Becht was born August 21, 1943, in Mobile, Alabama. She moved with her family to Melbourne, Florida, in 1950. She demonstrated an early interest for scientific research through ozone laboratory science fair projects and a talent search paper, Ozone--From Scientific Error to Space Age Plan. In 1961, she graduated with honors from Saint Anastasia High School, Fort Pierce, Florida. During the summer of 1961, she took courses at Brevard Engineering College in Melbourne. In September 1961, she began studies at Spring Hill College, Mobile, Alabama, where she received her degree Bachelor of Science with honors in May 1965, her major fields being in physics and chemistry and a minor in mathematics. She was vice-president of American Institute of Physics Student Section at Spring Hill College from 1963 to 1964. During her sophomore and junior years, she initiated projects involving the design, construction and testing of both gas and solid state lasers. During the summers of 1962, 1963, and 1964, she did course work at George Washington University, Washington D. C.

She came to the University of Florida in September 1965 to do graduate work in the Department of Nuclear Engineering Sciences, now Nuclear and Radiological Engineering. While in the Nuclear Engineering Sciences Department, she held a Graduate Assistantship, a College of Engineering Fellowship, and an Atomic Energy Commission Traineeship. Her first research study was on the heat transfer dynamics of a water droplet on a hotplate. Her interest in fusion led her to study plasma systems.

She received the degree Master of Science in Engineering with a major in plasma physics and minor in nuclear engineering. She designed, built, tested, and analyzed the first contained uranium plasma system at the University of Florida. Her thesis for the masters program was Development of a Plasma Chamber and Determination of the Radial Temperature Distribution of Mercury and Uranium Plasma Sources by Comparative Spectroscopic Analysis. During the succeeding years she continued graduate work on doctoral programs, majoring first in plasma physics and later in chemical physics. She studied total decomposition and real-time fragmentation of simple chloro-fluorocarbons using a computer interfaced hybrid gas chromatographic--time-of-flight mass spectrometer system, for assaying dosimetry samples and for monitoring mass fragments after injecting samples through a fast-flow microwave discharge system.

During those years, she also became involved with computer technology in education while raising a family. She carried out several research studies in instructional technology for the Florida Department of Education and made many presentations involving instructional technology at Florida Educational Technology Conferences, Florida Association of Science Teachers Conferences and National Science Teachers Association Conferences. She completed a graduate program for the degree Specialist in Education with a major in science education from the Department of Instruction and Curriculum. She has taught courses at the university, community college, and high school levels in the fields of computer science, physics, and chemistry.

She has had experience as a biochemist in the U.S. Department of Agriculture (USDA) and the University of Florida College of Veterinary Medicine (CVM). She performed studies at the insect taxonomy lab at USDA where she utilized a

computerized, integrated capillary gas chromatography--high-pressure liquid chromatography--diode array mass spectrometer (GC:HPLC-DA/MS) system for the analysis of insect extracts. She then transferred to a nutrition/lipoprotein biochemistry lab at CVM in the Department of Physiological Sciences where she performed clinical type sample analysis of blood plasma using electrophoresis and an absorption spectrophotometer for the quantitative measurement, using a capillary GC system, of fatty acid methyl esters derived from food extracts. Her research next carried her to a cardiovascular research lab where she developed and conducted methods using PAGE electrophoresis of ventricle heart tissue extracts for the assay of cardiac proteins (HC myosin). She then made a non-automated HPLC station functional from a quality control (QC) standpoint and performed basic drug assays for Lidocaine on blood plasma extracts.

Currently, she is completing her dissertation in the School of Teaching and Learning, majoring in curriculum and instruction with minors in both physics and chemistry. Her dissertation for the doctoral degree, Modeling the Effects of Multicontexual Physics Instruction on Learner Expectations and Understanding of Force and Motion Systems, connects the fields of science education and instructional technology using modeling theory on the science of learning. She is a member of many professional organizations and societies including the following: National Science Teachers Association, 1987 - present; Florida Association of Science Teachers, 1987 - present; American Association of Physics Teachers, 1995 - present; American Chemical Society, 1969-72; 1995 - present; American Organization of Analytical Chemist, 1995 - present; American Nuclear Society, 1965-69; 1988 - present; American Institute of Physics, 1961-65; 1995 - present; Kappa Delta Pi (1989); Phi Kappa Phi (1988); and Phi Delta Kappa (1981).

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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